XIV. *An Enquiry into the Cause and Extent of a Special Colour-relation between certain exposed Lepidopterous Pupæ and the Surfaces which immediately surround them.*

By Edward B. Poulton, *M.A., F.L.S.*

Communicated by Professor E. Ray Lankester, *F.R.S.*

Received and Read, February 10, 1887.

[Plate 26.]

Contents.

Introductory 311
Historical 312
Previously accepted explanations 317
Experiments upon *Vanessa Io* 317
Experiments upon *Vanessa urticæ* 319
Experiments upon *Vanessa atalanta* 398
The biological value of the gilded appearance in pupæ 399
Experiments upon *Papilio machaon* 406
Experiments upon *Pieris brassicæ* and *P. rapæ* 408
Observations upon the colours of the pupæ in the genus *Ephyra* 437
Summary 438
Description of Plate 439

Introductory.

The present investigation grew out of the enquiry into the colour-relation between Lepidopterous larvæ and their food-plants. In the search for the larval sense-organ which is affected by the light reflected from surrounding surfaces, great difficulty was experienced from the fact that the influences work slowly through the whole of larval life. Thus the ocelli must be eliminated by blinding five times in the life of each caterpillar, and there is always the chance of the skin being thrown off a little earlier than usual, in which case the success of the whole experiment might be endangered, for the coverings of the eyes are changed with the rest of the skin. It seemed probable that in the pupal colour-relation the influence must act during a short and rigidly limited time, in which experiments could be conducted with much hope of a successful isolation of the effective sense-organs.

14.11.87

The Royal Society is collaborating with JSTOR to digitize, preserve, and extend access to *Philosophical Transactions of the Royal Society of London. B.* www.jstor.org

Historical.

The first observation upon the colour-relation between Lepidopterous pupæ and surrounding surfaces was made by Mr. T. W. Wood, who exhibited in 1867 a number of pupæ of *Papilio machaon*, *Pieris brassicæ*, and *P. rapæ*, which corresponded in colour to the surfaces to which they were attached ('Entom. Soc. Proc.,' 1867, pp. xcix.–ci.). He also made some remarks on the subject, and expressed his opinion as to the nature of the susceptibility of these organisms in the following words:—"I find as the result of my experiments that the skin of the pupa is photographically sensitive for a few hours only after the caterpillar's skin has been shed; and, as might be expected, by putting the specimens in the sunshine at the time of changing, and surrounding them as much as possible with any desired colour, the most successful results have been obtained." There is no doubt that Mr. Wood placed the larvæ under the conditions he describes, and that in consequence the pupal colours were influenced, but if he had transferred the larvæ immediately before pupation to a surface of an entirely different colour the pupæ would have corresponded with the earlier surroundings. It seems strange that it never occurred to any previous observer to test the theory of pupal susceptibility in this simple manner. Mr. Wood exhibited green pupæ of *P. brassicæ*, found under a vine on a stone-coloured house, while none of the pupæ on other parts of the same house were of this colour. Very dark pupæ were shown which had been taken from a tarred fence, and from other dark surfaces, and in subdued light. One of the pupæ of this species, found on a white surface, was nearly white, and Mr. Wood also showed green, reddish, and dusky pupæ of *P. brassicæ* on surfaces of similar tints. He also stated that the pupa of *Vanessa polychloros*, when amongst foliage, is coloured like a withered elm leaf, being light reddish brown with a cluster of silvery metallic spots (dorsally placed) at the junction of thorax and abdomen. He also rightly asserted that the gilded appearance is not necessarily connected with the presence of Ichneumon larvæ within the pupæ. When the pupa is suspended to a wall the gilded appearance is not produced, and the pupa is of a mottled greyish colour. This observation is very important, for it contained the obvious implication that the metallic appearance may be controlled by the surroundings, as I have now proved it to be. In fact, Mr. Wood states, "I feel convinced that by the proper use of gilded surfaces the gilded chrysalides of *Vanessa*, and perhaps of other genera, would be obtained, and I hope to be able to try the experiment next season." I was not aware of Mr. Wood's last suggestion in 1867 when I undertook my experiments on the subject in 1886, and the arguments which induced me to make use of gilded surfaces are given at the beginning of the experiments. It certainly does seem strange that so remarkable, although so bold, a suggestion should not have been subjected to any test for nearly twenty years. The reason is perhaps to be found in Mr. Wood's unfortunate inclusion of *Papilio machaon* among the list of susceptible pupæ; for Mr. Bond, who knew the habits of this

species (which Mr. Wood expressly affirms were unknown to him), at once stated in the discussion which followed the paper that "he had had thousands of pupæ of *Papilio machaon*, and had often had the brown variety of pupa on a green ground-colour, whilst in some seasons he had obtained no brown specimens at all." My own experiments also clearly show, as far as the numbers employed could do so, that this species has no trace of susceptibility to surrounding colours. Mr. A. G. Butler also stated in the discussion that "he had obtained a red or rosy chrysalis of *Pieris rapæ*, which had undergone its transformation in a piece of scarlet cloth; and pupæ upon glass were generally of a pale slate colour." Concerning the former observation, *P. rapæ* is very commonly tinged with pink, and I think it almost certain that if the pupa was not removed from the scarlet surroundings the reflected light would intensify the pink tinge of the ground colour, and would thus produce a simulated resemblance between the two. I found that it was never safe to compare the colours of pupæ until they had been removed from the coloured surface on which pupation had taken place, and were arranged side by side upon white paper. Furthermore, in my experiments a dark red surface did not produce reddish, but dark, pupæ in *P. brassicæ*, and (as will be shown below) I can quite confirm Mr. Bond's criticism that reddish pupæ of *P. rapæ* are not found on red brick walls. At the same time Mr. Bond's objection to the main position taken up by Mr. Wood—that the pupæ of *Pieridæ* have some general resemblance with their surroundings—is without sufficient foundation, and the fact must now be generally admitted. His criticism that he has seen pupæ of *P. rapæ* with all shades of colour on the white painted woodwork of a greenhouse is valueless unless he can show that the dark forms are as common as when the pupæ are found on a tarred fence. Mr. Bond's observation that the variable pupæ of *Anthocaris cardamines* are not sensitive is important, but the species needs experimental investigation in order to confirm his observations.

The late Mr. Edward Newman also expresses an opinion adverse to Mr. Wood's observations upon *P. rapæ* in these words ('British Butterflies,' 1871, p. 162), "An ingenious—but, as I think, futile—attempt has been made to show that the colour of the chrysalis varies with the colour of the object to which it is attached."

Furthermore, Rev. J. Hellins ('Larvæ of British Butterflies,' &c., by William Buckler (Ray Society), 1885, p. 155) states of the pupæ of *P. rapæ*, "The colour seems very varied, but, as all the varieties occurred side by side on the cover of the tin box in which my larvæ were reared, I could not account for their difference." And of the different forms of *P. brassicæ* he also says, "These varieties were developed side by side in the same cage." It will be abundantly proved below that only *certain* colours affect each species which is sensitive to surrounding colours, and when other colours are made use of the pupæ either assume the commonest form, or, if very variable, are free to obey the influence of their varied hereditary or individual tendencies. And the use of tin as a background for the Pieridæ is especially likely to produce such results, for this surface is extremely unlike any of their natural

surroundings. Furthermore, it will be shown that the colour-relation is due to larval susceptibility during very many hours before pupation, so that, unless special precautions are taken, the larvæ may be disturbed or removed from one surface to another in feeding, observing, &c., and the results are likely to be highly irregular, for the boxes would always contain one colour which acts powerfully upon these two species, *i.e.*, the green leaves of the food-plant.

Professor MELDOLA, in a paper communicated to the Zoological Society ("On a certain Class of Cases of variable Protective Colouring in Insects," 'Zool. Soc. Proc.,' 1873, p. 153) confirms Mr. T. W. WOOD'S observations on the pupæ of the Pieridæ, for he states (p. 156), "I have observed a similar fact with respect to the pupæ of *Synchloë* (*Pieris*) *brassicæ* and *S. rapæ*, specimens from a black fence being generally darker than those found on walls." Professor MELDOLA informs me that this conclusion was obtained from the comparison of large numbers of individuals.

The next observation of the correspondence between the colours of variable pupæ and that of their surroundings is found in a paper by Mrs. M. E. BARBER, communicated by Mr. DARWIN to the Entomological Society of London ('Entom. Soc. Trans.,' 1874, p. 519). Mrs. BARBER had experimented with the pupæ of *Papilio nireus*, common in most parts of the Cape Colony. The larva itself in this species has also the power of colour adaptation to its surroundings, for Mrs. BARBER states that it is dark-green when found feeding upon orange trees, and lighter green upon *Vepris lanceolata*. In the natural state the pupal colours are always similar to those of the leaves of the food-plant, when pupation takes place among the leafy twigs—its usual surroundings. In Mrs. BARBER'S experiment the larvæ were reared "in a case with a glass cover; the case was partly made of wood and partly of brick: the colour of the wood was a dullish yellow, that of the brick a purplish-brown." Orange leaves, on which the larvæ fed, were placed in the case, and also a branch of the common bottle-brush shrub, of which the dead leaves were pale-green. Of the resulting pupæ some were fixed to the orange leaves, and were of the usual deep-green colour, like that of the surrounding leaves; others were fixed "to the bottle-brush branch, and these became pale yellowish-green pupæ of precisely the same colour as the half-dried leaves. One of the caterpillars in particular affixed itself upon the wooden framework of the case, where the wood and the brick came in contact with each other, and to my surprise this caterpillar, after throwing off its bright-green skin, assumed the colours of *both the wood and the brick*, its under-side resembling that of the wood to which it was attached, and the upper side that of the adjacent brickwork."

"Some days later another specimen affixed itself to the wooden frame of the case, and then became a yellowish pupa of the same colour as the wooden frame." Mrs. BARBER then tried the effect of surrounding a caterpillar before pupation with scarlet cloth, but the resulting pupa was of the common deep-green form, in which, however, the coloured spots usually present in this variety were of a brighter red. Mrs. BARBER suggests that these correspondences of colour may be analogous to those

of the Chamæleon, or may be "a sun-picture or photograph"; and in support of the latter view (which has been commonly accepted up to the present date) the writer calls attention to the transparent surface of the freshly-formed pupa, which might be sensitive to light. In my experiments, described below, I did not meet with any parti-coloured pupæ, and it is to be noted that a difference between the colours of the dorsal and ventral surfaces is common in pupæ. It would be satisfactory to expose this highly sensitive insect to conflicting colours arranged antero-posteriorly instead of dorso-ventrally. Although Mrs. BARBER's figure certainly supports the conclusion that the different pupal surfaces may be influenced independently, the conclusion is too important to rest on a single instance, and it is to be much hoped that the subject will be re-investigated. In the discussion which followed Mrs. BARBER'S paper ('Entom. Soc. Proc.,' 1874, p. xxiv.), Professor MELDOLA remarked that "the action of light upon the sensitive skin of a pupa had no analogy with its action on any known photographic chemical. No known substance retained permanently the colour reflected on it by adjacent objects."

Mr. J. P. MANSEL WEALE makes a further interesting addition to the history of the subject in his record of experiments upon the larvæ of *Acræa esebria* (see 'Entom. Soc. Trans.,' 1877, p. 271), also in South Africa. He says: "Some larvæ I confined in a dark box, and found that the coloration of the pupæ (usually white, with thin black and orange markings) was materially altered and darkened, so as closely to resemble those of *Acræa horta*, but the individuals were as varied in colour as those raised under ordinary daylight. This darkening of colour I have found to be very common under the same circumstances in pupæ belonging to different families of Butterflies. Both larvæ and pupæ of those Acræas known to me are found in conspicuous places without any attempt at concealment."

Mr. J. P. MANSEL WEALE also records, on p. 275 of the same paper, some interesting experiments upon the variable pupæ of *Callosune keiskamma* and those of *Eronia cleodora*. He says: "With reference to the changes in the colour of pupæ, I believe a very wide field of research is open, and with the improved modes of microscopical examination under the spectroscope important revelations on the subject of variation will be discovered. I here give the results of some very rude experiments on this subject. Most of the specimens were reared in glass test-tubes exposed on coloured cards, in which they were partially enveloped. They were constantly supplied with as little food as possible, in order that their full exposure to the colour should not be interfered with.

"Pupæ of *C. keiskamma*.

(1.) On dead leaves away from light	Dark brown.
(2.) On stem and on vermilion cards	Pale ochreous.
(3.) On vermilion card	Pale bluish-green.
(4.) Exposed on bush in nature and on yellow gamboge cards	Bright green.
(5.) On glass tumbler	Pale yellowish-green.
(6.) On green (cobalt and gamboge)	Ochreous.
(7.) On cobalt-blue	Greenish-white.

"On a white surface pupæ of *Eronia cleodora* became so pale-coloured as to be almost translucent, the marks on the ventral aspect of the abdomen being almost obliterated, and the bright yellow-green colour usually predominant almost invisible."

Mr. TRIMEN confirmed Mrs. BARBER'S observations upon *P. nireus* in some experiments conducted upon *Papilio demoleus*, which is common at Cape Town. These results have not been published, but Mr. TRIMEN has kindly sent me an account of them in a letter. He says, "I left my *Demoleus* larvæ full liberty, within the range of their breeding-cage, to attach themselves to any of the bands of colour with which the sides of the cage were provided. I had noticed in nature that the pupæ attached to the green upper twigs of the food-plants among the leaves were always more or less green or greenish, while those on the more brownish or greyish stems were coloured like the latter. Though more of these larvæ suspended themselves to the food-plant, the remainder showed no apparent choice among the colours, but attached themselves indiscriminately all about. The colours which seemed certainly to directly affect those of the pupæ were (irrespective of black, which made them a little darker) green, yellow, and reddish-brown, these tints being more or less reproduced. Bright red and bright blue had no apparent effect. I did not repeat the experiment, finding this one so confirmatory of Mrs. BARBER'S observations on another species of the same genus."

Finally, Professor MELDOLA, knowing that I was looking out for any notices of the literature of the subject, kindly sent me the following translation of an important note in 'Kosmos,' by FRITZ MÜLLER, showing that the pupæ of *Papilio polydamus*, although dimorphic—green and brown—like our own *P. machaon*, are, nevertheless, like it, not susceptible to the influence of surrounding colours.

"According to the observations and experiments of WOOD on *P. rapæ*, and of Mrs. BARBER on *P. nireus*, the colour of the pupæ in these Butterflies is determined by the colour of the object on which they pupate. Nevertheless, this does not hold good for all Butterflies of which the pupæ are differently coloured; it is not the case, *e.g.*, in *P. polydamus*. The pupæ of this Butterfly, which in former years I saw in large numbers, are either green or brown, and I have never found intermediate colours. The ground colour of the larva which lives on Aristolochia varies within wide limits; pure black and bright yellowish or reddish-brown caterpillars are seldom found, but all possible stages between these extreme colours are common. The colour of the larva, however, has nothing to do with that of the pupa, and from both kinds of pupæ similarly coloured Butterflies are developed, both males and females.

The Butterfly always lays several (4 to 6) eggs close together; till the second moult, the young larvæ also keep together; they eat the same leaf and sit close together when at rest (like the social larvæ of *P. evander*, till they pupate). Such a society of young larvæ that I observed from the eggs in my garden I recently transferred to a large glass case before they distributed themselves over different leaves, and from this, as they prepared for pupation (*i.e.*, when their excrement,

instead of being hard and dry, became fluid), to a box, of which the two larger sides consisted of white gauze, and the narrower sides and the bottom and top (cover) of grey pasteboard. They fastened themselves to a thin defoliated stalk of Aristolochia. Of the five larvæ, two changed into brown and three into green pupæ; a brown and green pupa were on the same stalk, removed by less than their own length from each other. They emerged from the egg at the same time and shed their larval skin at the same time, whilst during their whole life (larval) they were exposed to the same external conditions, the same action of light, and to the time of pupation had neither brown nor green in their surroundings. In this case, therefore, the influence of the colour of the environment certainly cannot have affected the colour of the pupa." ('Kosmos,' vol. 12, p. 448.)

Previously accepted explanations.

The theory of the moist, fresh, pupal surface as "photographically sensitive" was obviously a metaphor borrowed from the sensitive plate of photography, and Professor MELDOLA pointed out that there could be no real analogy between the two processes. Furthermore, there was the difficulty that the explanation failed to account for the colour of those pupæ which throw off the larval skin on a dark night, for the pupal colours very quickly deepen into their permanent condition. Considering these difficulties, and knowing that the explanation had never been tested by "transference" experiments, I came to the investigation with the firm conviction that it would be found that the problem was essentially physiological, and that the physico-chemical changes were merely the results of far more complicated physiological processes. It furthermore seemed probable that the reflected light would be found to act—for a period long enough to include, under any circumstances, many hours of daylight—upon some sensitive area in the larva as it rested upon a coloured surface before pupation, and it appeared likely that such a sensitive area might be defined by experiment. The investigation was conducted during the summer and autumn of 1886. The object of the present paper is to give an account of the investigation of the questions alluded to above, and its results are therefore preliminary in the sense that they afford a foundation for future work, in which the physiological changes induced by varying colour must be sought out by histological and other methods. Such an investigation I hope shortly to undertake.

Experiments upon Vanessa Io.

This pupa is dimorphic, the common form being "pale grey, but freckled all over with smoky black" (BUCKLER), with a small amount of gilding, while the less common form is bright yellowish-green, with a large amount of gold. I determined to ascertain whether the latter form could be produced by placing the larvæ in

appropriate coloured surroundings before pupation. Mr. E. D. Y. Pode very kindly sent me six nearly full-grown larvæ from South Devonshire, and these were placed in a glass cylinder covered with two thicknesses of green tissue paper, of which the outer layer had become very yellowish from the action of light. The paper being very transparent, the larvæ in the cylinder were exposed to a yellowish-green light, mixed with a great deal of white light. All the six larvæ suspended themselves from the paper roof of the cylinder, and five changed into the yellowish-green variety. One of these was figured (see Plate 26, fig. 7; natural size). The sixth was detected a few minutes after the larval skin had been thrown off, for the surface was moist and the shape unformed. It was exactly in the condition of assumed photographic sensitiveness, described by previous observers. I therefore cut it down immediately and pinned it up in an opaque box with a tightly fitting lid, the whole interior surface being lined with black paper. In a few hours I opened the box, and found the pupa a yellowish-green variety, exactly like the others. It is therefore quite clear that the influence had worked previously—during the larval stage. There can be no doubt that this result without a single exception, is conclusive, when the comparative rarity of the green variety is considered. In all my previous experience I have only obtained this variety singly among large numbers of the dark form, and I have *never* seen it among the numerous pupæ found upon palings and walls, and I have never found the pupa of this species in other situations—upon the leaves of its food-plant or other plants. Being anxious to ascertain whether other observers have had the latter experience, and to know its results, I wrote to Mr. W. H. Harwood, of Colchester, who has been a most keen observer for many years. In his reply he says, "I have sometimes found the pale form of *Io* on the under-side of nettle leaves, but do not remember meeting with the dark one." From this observation it is seen that the power of colour adaptation, which experiment has proved to exist in this species, is actually turned to account in the wild state. Newman, in 'British Butterflies,' p. 61, does not recognise the pupal dimorphism, for he says, "the colour of the chrysalis is green; as the chrysalis darkens its colour deepens, but the green tint is never entirely lost." Buckler, on the other hand (Ray Society, 1885), fully recognises the two forms. While the single individual, which was transplanted to a colour which must presumably tend towards an opposite effect, seems conclusive against the former theory of pupal as opposed to larval sensitiveness, the same results are better seen in *Vanessa urticæ*, where they were worked out in great detail, and in which the proof becomes irresistible from the large numbers employed in the experiments. The cuticles of the left pupal wings of the two varieties are figured in Plate 26, figs. 10 and 11, both × 7, and the immense differences in the tint of the cuticular ground colour and the amounts of pigment present are well seen.

Experiments upon Vanessa urticæ.

There are certain reasons why this species is peculiarly fitted for the purpose of the present investigation. It is exceedingly common throughout the whole of the summer months, and its food-plant—nettle—is abundant everywhere; above all, the larvæ are gregarious, living on webs when young, scattering when older, but never to such an extent that more than a few yards intervene between the most widely separated larvæ. Such companies are made up of large numbers of larvæ (examples of the numbers will be given below), and, as each of them results from the eggs laid by a single butterfly, it follows that in any series of experiments conducted upon the individuals of a company the possible errors which might follow from different hereditary tendencies due to different parents—of unknown, but presumably varying, histories in the larval state—are completely eliminated. At the same time, the numbers are amply sufficient to admit of the experimental investigation being varied and, at the same time, carried on in the most complete manner among the offspring of a single pair of butterflies. During the whole summer I did not meet with a single instance in which the larvæ of one colony could be mistaken for those of another, for in nearly all cases each company occupied a separate clump of nettles, and in the few cases in which more than one occurred upon a very large nettle-bed the larvæ of the different companies were at different stages of growth, and, furthermore, on different parts of the bed. In the following series of experiments the numbers III.–XIII. (both inclusive) correspond to eleven companies, of which the respective larvæ were always most carefully separated.

I.—Early in the summer I began to experiment with this species. The larvæ, when found suspended in the breeding cages, were removed, and fixed against black, white, and green paper, in a strong light. The larvæ in all cases pupated shortly after transference, and there were no apparent effects wrought upon the resulting pupæ. Later investigations showed that these negative results were due to the shortness of the time during which the larvæ had been exposed to the influence of colour. The experiments also proved that the moist surface of the freshly exposed pupa is not sensitive to colour influences. A little later, I again experimented with an orange background, about twelve larvæ being kept for a large part of their lives in a cylinder lined with this colour. The pupæ were all of that very common variety which will be represented below as degree (3), and such negative results seem to prove that the species is not susceptible to such surroundings.

II.—I had asked Mr. Pode to procure some more larvæ of *V. Io* for me, but, as it was too late for the species, he sent a large number of *V. urticæ*. These consisted of individuals of several companies and of different ages, but in this case it was not considered safe to attempt to sort them. In estimating the pupal colours, it was

necessary to make a standard of comparison by the selection of well-marked degrees of colour, for in this species there is no distinct dimorphism, but all variations are connected by intervening forms. At this period of the investigation I arranged the pupæ according to the following standard, which was subsequently rendered more elaborate as the experiments became more precise. (Six of the most important varieties are figured in Plate 26, figs. 1–6, × 2.)

(1) Very unusually dark, almost black; very little gold, or none.
(2) Dark normal form; dark grey, often with a slight pinkish tinge, with very little gold, or none.
(3) Light normal form; light grey, often with a pronounced pinkish tinge; more gold than (2), occasionally none.
(4) Lighter than (3); the pinkish tinge often very pronounced, and usually a large amount of gold.
(5) Very light forms; generally completely covered with gold.

It will be noticed that the dark colour due to pigment is shown by the above list to be developed in inverse ratio to the amount of gilded appearance, which depends upon a totally different optical condition, and pigment is absent from the gilt spots of the darkest varieties. The pink tinge forms the ground-colour of the pigment tints, while the darker forms are due to the increase in number of dark cloudy spots and the widening and multiplication of the strands of similar dark reticulations, which, in the most extreme forms, completely obscure the ground-colour. The pigment of both ground-colour and the dark spots is cuticular in position. Two degrees of pigmentation are shown in figs. 8–9, × 7, Plate 26, the pupal wings alone being represented, but affording a fair criterion of the general development of pigment on the pupal surface.

In comparing the results of experiments by means of a standard, it is obvious that the classification of any series of pupæ is, at any rate, correct as affording a test of the relative amount of pigment, gilding, &c., upon the pupæ compared together at any one time. But the experiments were continued for a much longer time than that passed in the pupal stage by this species, and hence it is possible that the classification of the pupæ in the later experiments will not bear too close a comparison with that of the earlier ones. Nevertheless, I do not think that there was much difference, and when the times for taking results happened to come sufficiently near together I always classified the pupæ together, although taking notes of each company separately. But, however great be the want of parallelism between the arrangement of the initial and terminal experiments, the results would not be invalidated, for the numbers made use of in several of the series of experiments which became ready for classification together were amply sufficient to ensure conclusive results, and for each series classified together the arrangement would certainly hold good.

Mr. Pode's larvæ were divided into several lots, which are described as follows,

together with the resulting pupal colours, which are given in numbers corresponding to the standard list described above. The comparison was made August 19, 1886.

A. A number of larvæ were placed in a transparent glass cylinder on a white plate, which, however, soon became dark from the larval fæces. The food-plant passed through a hole in the plate into water beneath, and the top of the cylinder was covered with white muslin, much darkened and discoloured by age. Upon this disc of muslin, only 9 centims. in diameter, 18 pupæ were crowded, not one occurring in any other part. These were coloured as follows :—

4	pupæ were	(1).
6	„	(2).
6	„	(3), 2 of these approaching (2).
2	„	dead and discoloured.
18		

It will be seen by a comparison with other experiments that the especial darkness of this lot of pupæ was due to the mutual influence of the dark bodies of the larvæ themselves hanging close together upon a limited space.

B. Another lot of larvæ were placed in a larger cylinder, but with arrangements similar in other respects. Eight pupæ were suspended from the muslin top, 1·10 decimetres in diameter, while five others were suspended from the food-plant. They were coloured as follows :—

Of the 5	pupæ	on the food-plant	1	was (2).
„	„	„	2	were (3).
„	„	„	2	were dead and discoloured.
Of the 8	„	muslin	1	had produced an imago, but the pupa was probably (3); certainly this or (2).
„	„	„	1	was (2).
„	„	„	1	was (4), with the gold of (5).
„	„	„	5	were dead and discoloured.
			13	

This set compares in an interesting way with the last; being far less crowded on the larger area of muslin, there was a much smaller proportion of dark environment to each larva, and the whitish muslin could also produce its effect. Hence a much lighter series of pupæ are obtained, with more gold upon them. Comparisons of this kind led me to continue the investigations upon this species with much greater minuteness, as will be seen below.

C. Another lot of larvæ were placed in a cylinder surrounded by a single layer of green tissue-paper, which had become very yellowish-green from the action of light.

Of the 14 pupæ, 13 were suspended from the green roof—7·0 centimetres in diameter—and one from the food-plant, but the latter and seven of the former were dead and discoloured. On August 9, at 10.45 P.M., 11 individuals had already pupated on the roof, and two larvæ were suspended before pupation. At this time the roof was cut off and pinned in close proximity to a north window, so that the pupæ, &c., still hung vertically. At 10.5 A.M., August 10, these two larvæ had pupated, but evidently quite recently, for the surface of both was still greenish. Compared with the rest on August 19, these results were obtained :—

Of the 4 living pupæ which threw off the larval skin in the cylinder	4 were (3), 2 of them with rather unusual gold, and tending in lightness also towards (4).
Of the 2 living pupæ which threw off the larval skin in the strong north light	1 was (3). 1 „ (4).
	(6)

It might be supposed that the greater amount of light perhaps influenced the colour of the two larvæ which pupated latest, and which were exposed in the window for 10–11 hours, but the evidence is insufficient, as the difference between the two sets of pupæ is so small.

D. Another lot of larvæ were placed in a cylinder similar to the last. On August 9, at 10.30 P.M., the yellowish-green paper roof, 7·5 centimetres in diameter, was cut off and pinned in a north window as before. At that time four pupæ were hanging from the paper, to which nine larvæ were also suspended. By 10.5 A.M., August 10, four had pupated some hours, and two more quite recently, while the three remaining larvæ pupated at some time (unknown) later than 10.5 A.M. All these were marked and compared on August 19, the following results being obtained :—

Of the 4 which pupated in the cylinder	2 were (2). 2 „ (3).
„ 4 „ „ after a short time in the north light	1 was (1). 3 were (3), 2 of them approaching (2) very closely and really intermediate.
„ 2 „ „ „ longer „ „	1 was (2). 1 „ (3), with rather more gold than usual.
„ 3 „ „ „ still longer „ „	3 were (3), 2 of them tending towards (2).
13	

In this case it is seen that practically no effect was produced by the light, a fact which I afterwards learnt was to be expected, for a strong light merely tends towards the special coloration which follows from the illumination of the surroundings of the pupa, if such surroundings are coloured by any of the tints for which the organism is sensitive. In all the experiments with green cylinders I had in mind the green form

of *V. Io* and the green form of so many other dimorphic species (*Papilio machaon*, *Anthocaris cardamines*, &c.). But I was soon convinced that *Vanessa urticæ* has no green form, and therefore in these experiments, in which green was the predominant colour, the results produced showed no fixed relation to the chief part of the surroundings, but must have been determined by individual tendencies irrespective of external stimuli, except such as were provided by the amount of shade in such covered cylinders, and by the presence of neighbouring larvæ and pupæ.

E. Another lot of larvæ were placed in a cylinder similar to the last, except that a new roof had been recently added, consisting of two layers of green tissue-paper, while the sides were surrounded by a single layer which had become very transparent and yellowish. On August 19 there were five pupæ, of which four were on the comparatively opaque and dark roof, while one was suspended from the bare stem of the food-plant and fully exposed to the yellow light coming in through the sides. The colours were :—

Of the 4 pupæ on the roof . . .	1 was	(2).
	3 were	(3), 1 of them with unusual gold.
On the food-plant	1 was	(5), splendidly golden all over.
	5	

This experiment, more than any other in Series II., convinced me that the pupæ vary in lightness and darkness, in brilliancy and dulness, and that it was useless to continue the employment of green cylinders, but that such colours as black and white would be far more likely to yield satisfactory results.

Three larvæ were removed from this cylinder on August 13, and were treated in a manner which will be described below.

F. Another lot of larvæ were placed in a cylinder also covered with the same green paper, but in this instance there were two layers over the cylinder as well as the roof; but the paper was faded, becoming yellowish and comparatively transparent. The larvæ in this cylinder were blinded by painting over the region of the ocelli with black varnish (a quickly-drying photographic varnish, rendered opaque by the addition of lamp-black). Five pupæ were suspended from the roof, and one was lying on the floor. The colours were :—

Of the 5 pupæ on the roof . . .	3 were	(2), 1 with rather more gold than the others.
	1 was	(3).
	1 „	(5).
On the floor	1 „	(2).
	6	

It is seen that the blinding made no difference to the result, at any rate in the direction of producing darker pupæ. This conclusion will be confirmed later.

G. Another lot of larvæ were placed in a small cylinder surrounded by two layers of black tissue-paper, and with a roof of two layers. Only a single larva reached the pupal state, but this was an exceedingly dark and well-marked (1).

This result also contributed greatly towards the frequent use of black surroundings in subsequent experiments.

H. Another lot were placed in a cylinder covered, as before, with one layer of green paper, yellowish on the sides, but recently renewed and greener on the roof. Of the seven pupæ, four were on the roof and three on the food-plant. The results were :—

Of the 4 pupæ on the roof . . .	3	were (3).
	1	was (5), with the usual extreme development of gold.
„ 3 „ „ food-plant .	1	„ (1).
	2	were (3), 1 with rather more gold than usual.
	7	

There is nothing to add to what has been said before concerning the colour of pupæ in the green cylinders. On August 13 three larvæ were removed from this cylinder and treated in a manner which will be described.

I. Although all the above-mentioned pupæ in Series II. were compared together on August 19 (because by that date nearly all had reached the pupal stage), I had been watching the results seen in the various cylinders for many days, and had started further experiments, which were suggested by those already described, so that both series of results could be compared together on the above-mentioned date. The effect in the black cylinder (G.), and that in E., having convinced me that black and white would be good colours with which to experiment, it seemed clear that, if successful, there would be a more decided colour-relation between the dark pupæ and the black surroundings than between the brilliantly metallic pupæ and their white environment; and if the former relation was, as it seemed to be, most real and protective, it appeared advisable to offer the pupa a surface which would harmonise with its gilded form as completely as the black surface did with the darker variety. Having already seen a few instances of the gilding developed upon No. (5), it was quite clear that nothing could harmonise so well with it as the brilliant colour of metallic gold-leaf. On entering upon such an experiment, I was not prepared for the extraordinary success with which it was attended. But the conclusions from the other experiments led up to this as a crucial test, and it certainly seemed well worth the trial. I procured some paper covered with gold-leaf, and with it lined the inside of a box which was provided with a glass front, and was placed facing a strong east light. The side of the box, which formed the floor in this position, was covered with brown paper. A vertical partition, also gilded, separated the box into two equal compartments, which possessed every

condition in the way of illumination, &c., in common. Care was also taken that the amount and distribution of food-plant should be as nearly equal as possible in the two compartments.

(α) Thirteen larvæ were placed in one compartment, and, as eight of these were dead on August 13, three were added from the set described as H., and three from that labelled E. On August 19 there were eight pupæ, of which four were dead and discoloured, and of the others one was on the roof and three on the food-plant. The results were :—

Of the 3 on the food-plant	1	was (3).	
	1	„ (4)	With the splendid golden appearance which is usual in these degrees of colour.
	1	„ (5)	
On the roof	1	„ (5)	
	4		

This was a very complete result as compared with those previously recorded, and left no doubt that the metallic appearance can be influenced in the most remarkable way by the use of surrounding surfaces with a corresponding colour. Such a conclusion will receive the most complete confirmation below.

(β) In the other compartment 12 larvæ were placed after having been blinded as carefully as possible. The two pupæ which were ultimately formed possessed the following degrees of colour :—

1 on the food-plant	. . .	was (5).
1 „ floor (brown paper)	„	(3), but a light one.

Here again the blinding produced no effect on the colour as far as the evidence goes.

J. Two exactly similar white gas globes of "opal" glass were selected, and the open upper end of each was covered with white paper, each globe being placed on a perforated white plate. The lower end of the stem of the food-plant (in small and, as far as possible, equal amounts) passed through the perforation into water, while the leaves and stem above the plate were in each case introduced into the globe through its lower opening as the globe itself was lowered on to the plate. The globes were placed in a strong north light.

(α) In one globe 10 larvæ were placed, and by August 19 four had pupated upon the leaves of the food-plant in all cases, while three larvæ were still feeding (three having died).

Of the 4 pupæ	1	was (3).
	3	were (5), typical.

Hence the bright white surroundings produced very striking results.

(β) 10 blinded larvæ were placed in the other globe, and five had pupated by

August 19. Of these, two were dead and discoloured, one was on the roof, and two on the food-plant.

Of the 2 on the food-plant . .	1	was (2).
	1	,, (3).
The 1 on the roof		,, (5) typical.

These pupæ are certainly darker, as a whole, than the unblinded ones, but the difference is not great enough to suggest the blinding as a necessary cause, while other experiments (to follow) clearly show that it cannot have been effective in this way.

This concludes the experiments conducted upon the larvæ of Series II., kindly sent me by Mr. PODE. The great mortality was due to the fact that the larvæ were sent very young, and were thus brought up for nearly the whole period of larval life in unnatural conditions. In the following experiments I made use of larvæ which were found in various localities near Oxford, and which were allowed to remain upon the nettle-bed until they were nearly mature. In this way I secured a very high percentage of pupæ. Nevertheless, in the experiments just recorded (II.), that insight into the colour sensitiveness of the species was gained which rendered all the following experiments possible and suggested the various modifications and details.

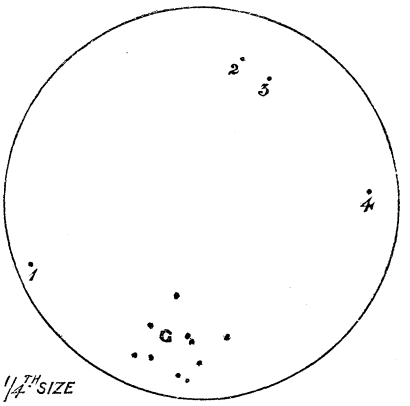
III.—A company of mature larvæ was found August 15 beside the towing-path of the "Upper River," near Oxford. In the press of other work they were in some cases temporarily placed in short, wide, glass cylinders, covered with sheets of glass, until the night of August 16, when they were counted and to some extent re-arranged, but in the meantime they had ceased to feed; in fact, the great majority did not eat anything at all after capture. They were arranged as follows, and were all compared August 21, both together and with those of Series II.

A. A clear glass cylinder was employed, 2·07 decimetres in internal diameter and 7·0 centimetres in height. This was placed upon a floor of white paper, upon which a small quantity of the food-plant was lying horizontally, and the cylinder was covered with a sheet of white translucent "opal" glass, forming the roof. The larvæ described in this division, although first counted and noted on the night of August 16, had previously been in the same cylinder with the same white roof (although without the paper floor, as the cylinder merely rested on the ordinary floor boarding of the room). On the night of the 16th they were placed on a table about six feet from a very large window, so as to be exposed to a good east light during the day. Before this time they had been upon the floor of the room under the shadow of the table. When re-arranged on the 16th, 11 larvæ were hanging from the roof preparatory to pupation, and by 4 P.M. on the 17th four had pupated and were removed, and by the same evening seven more had also changed. When compared on August 21st, there were 15 pupæ arranged and coloured as follows:—

10 suspended from the roof in a smallish group	4 removed Aug. 17, of which all were light	(3), 3 with more gold than usual but not the gold of (4).
	6 remained hanging, of which 5 were	(3), 2 lightish.
	1 was	(4).
4 isolated, suspended from various parts of the roof, of which 2 were		(4), 1 with unusual gold, but not equal to (5).
	2 „	(5).
1 isolated, lying on the white floor, not attached to food-plant; it was		(4).
15		

The relative positions of the pupæ are shown in fig. 1 ($\frac{1}{4}$-size).

Fig. 1.



The circle represents one-fourth the size of the white-paper roof, looked at from below, so that the points of attachment of the pupæ are seen (indicated by the 14 black dots). The dots 1–4 mark the positions of the 4 isolated pupæ. The 10 dots at G similarly show the positions of the 10 pupæ, which were arranged in a compact group. Each dot corresponds to the position of the boss of silk to which the pupa was fixed.

Various results come out very clearly from this experiment :—

(1.) The larvæ were captured on the afternoon of August 15, and 11 out of 15 had pupated by the evening of August 17, while seven of these pupated between the afternoon and evening of this day. I do not think that any of these larvæ ate anything after capture; it is quite safe to assume that the 11 which first changed did not feed. It is therefore probable that by far the greatest part of the period intervening between capture and pupation (about 48 hours) corresponded to the normal period which intervenes between the cessation of feeding and pupation. I have frequently noticed that when mature larvæ, almost ready to cease feeding, are captured in the field they do not eat at all in captivity, but immediately prepare for pupation, the change appearing to be slightly hurried on by the shock given to the larva. In this species the period between the cessation of feeding and pupation, which will in future be called the "preparatory period," consists of three stages :—

Stage I., in which the larva quits its food-plant and hurries about, seeking for some place upon which to pupate.

Stage II., in which the larva rests motionless upon the selected surface and towards the end of the stage spins the boss of silk for its subsequent suspension.

Stage III., in which the larva hangs suspended by its posterior claspers from a boss of silk.

It is to be noted that Stage I. must be of very indefinite length, depending chiefly upon the varying proximity of places suitable for pupation. It will be shown that if such suitable surfaces are not reached the larva finally makes the best of anything which happens to be near, or often pupates in a horizontal position without suspending itself. Under ordinary circumstances the larva is exposed to the effective colour influence during Stages II. and III. only, for in the previous stage it is wandering over surfaces of various colours; hence the pupal colour must, as a rule, be determined in the two later stages. Further experiments will show that these important stages are of more constant length than the first stage.

(2.) The experiment shows the great power of the white surface in producing light and gilded varieties.

(3.) It shows the great influence of closely adjacent, but comparatively small, dark objects in modifying the effect which would have followed from a white surface. Thus, of the 10 larvæ, arranged in a small group so that the dark-skinned component individuals were exposed to mutual influence, 9 were (3) and 1 was (4), while of the 5 larvæ isolated upon the roof and floor 3 were (4) and 2 were (5). No importance is to be attributed to the removal of the four first-formed pupæ on August 17 (afternoon), because any effect produced by them on their neighbours must have been wrought before the transference took place.

B. Another set of larvæ were blinded, and (August 16, evening) placed in a cylinder of almost the same size (2·16 decimetres in internal diameter, and 1·02 decimetres in height), with a similar roof and floor and amount of food, and the same conditions of light. It is, however, to be noted as very important that these larvæ had not been previously exposed to the influence of a white roof, but were taken from a cylinder covered with a sheet of green glass, the whole being placed upon the floor in the shadow of the table. To compensate for this, the least mature larvæ were selected, *i.e.*, those which, as far as possible, were feeding, or had not passed beyond Stage I. of the period before pupation. Nevertheless, the comparison with A. is unsatisfactory, because in selecting the least advanced larvæ out of very large numbers the results are liable to be influenced by the fact that such larvæ are often less healthy than the others, and frequently do not ultimately attain the average size. On August 21 the following results were obtained :—

3	lying on the floor, not attached to the food	2 deformed and with larval heads attached, both apparently . . . . . light (2).
		1 normal . . . . . light (2).
3	suspended to the glass side of cylinder	2 deformed as above, both apparently. . . . (5).
		1 normal . . . . . light (3).
2	suspended to the roof (about 1·9 centimetres apart)	both (4), but with little gold for this stage.
8		

The deformity is due to the fact that the larvæ, when blinded, dash their heads about, and so tend to spread the varnish over a much larger area, and it is thus liable to harden on the top of the head, and to prevent the latter from splitting in the complete manner which is necessary for ecdysis.

I have been obliged to quote an "apparent" degree of colour for the deformed pupæ, because it was difficult to judge them by the same standard as the normal ones. In the result it is to be noted that the white roof produced a strong effect on the pupæ suspended from it, and that those attached to the side of the low cylinder also came under its influence. The floor was white, but the relative proximity of the dark leaves and stems of the food-plant may have made all the difference. On the other hand, these pupæ were not crowded together, as in the majority of the A. division. This last important difference in arrangement, which must certainly produce some considerable effect upon colour, together with the possible sources of error introduced by the food necessary for many larvæ, induced me to alter the conditions of these comparison experiments in a manner which will be described below.

Allowing for all uncertainties, there is no sufficient ground in the respective results of these two divisions (A. and B.) for the belief that the ocelli represent the larval sensory surface through which the colour influence makes itself felt.

C. Nearly all the remaining larvæ were placed (August 16, evening) in a large cylinder (2·39 decimetres in internal diameter and 1·02 decimetres in height) covered with one layer of black tissue-paper, and with a similar roof and floor. Thus, although the surrounding surfaces were all black, a considerable amount of light could enter the cylinder. These larvæ had previously been in the green-glass covered cylinder from which those of the B. division were taken. Compared with the others, and with Series II., the results were:—

3	suspended from the roof	2 near together, both (3), one of them light (3).
		1 isolated and . . . (3), darkish.
1	suspended from the side	(4).
2	on the floor	were both (2).
6		

Further experiments will show that these results were largely due to the exposure previous to the evening of the 16th. I was unable to take notes of the hours at which suspension or pupation took place in this or the B. division, but, as the latter

consisted of the least advanced larvæ, very carefully selected, it follows that the remainder, which (with two exceptions, forming D division) formed this division, were comparatively mature and doubtless far advanced in Stage II. of the preparatory period when the black roof was added. Nevertheless the results are important when taken with others, as showing that the influence works upon the larva for some considerable time before pupation, and therefore, when it is only introduced shortly before the change, great effects are not produced; but the same conclusion will be reached by far more careful experiments, to be described below.

D. Two larvæ were already suspended from the green glass cover alluded to above on the evening of the 16th. The glass was placed in a vertical position in a strong north light, the larvæ being on the side towards the room. On comparing, their colours were :—

2 pupæ, both (3), 1 darkish and 1 lightish.

Thus 31 pupæ were obtained from Series III., and I do not think that any of the larvæ died. I did not, at the time, know the number of larvæ in a company of average size, or it would have been clear that the captured larvæ were merely the remnant of a company of which the large majority had already sought pupation. Being greatly in want of material, I searched very carefully, and, I believe, obtained all the larvæ left on the nettle-bed. Had I known that the larvæ were in this position, and therefore almost certain to pupate directly, I should have acted differently. Further experiments will show that, to obtain sufficiently accurate results, the most exacting demands are made upon time and at a moment's notice; for as soon as the material is obtained the first few hours may prove to be the most important of all.

Nevertheless, the conclusions from A. division are most interesting, and thoroughly borne out by other work; and, allowing for all sources of error, the comparison between A. and B. is also satisfactory.

IV.—Another company of mature larvæ was found, also on August 15, on a large patch of nettles in Binsey churchyard. On the evening of the 15th these were placed in two cylinders, one very large and covered with a sheet of clear glass, the other smaller and covered with a sheet of "opal" glass. Both were on the floor, in the shadow of the table. On the next day they were re-arranged according to the following divisions. Comparison of the pupæ, together with those of all previous series except I., took place August 22.

A. In the afternoon of the 16th 12 larvæ were taken from the large cylinder, and were placed in a small cylinder (6·2 centimetres in internal diameter; 1·18 decimetres in height) covered with two layers of black tissue-paper, with a similar roof, also of two layers, and a black floor. The larvæ which were selected had not yet entered

Stages II. or III. of the preparatory period. All the 12 pupated upon the roof, and were therefore crowded close together on a black disc 6·2 centimetres in diameter. The results were :—

Of the 12 pupæ . 3 were (1), not very decidedly black for this division } Hence these were very hard to
4 „ (2), decidedly dark for this division } separate.
5 „ (3), 4 of them dark (3), one normal, but in all 5 there was the normal gold and pink ground-tint; but the dark pigment, where present, was much blacker than in the normal (3), so that these 5 presented a very different appearance from the (3) of other cylinders.

It was interesting to note that seven out of the 12 were much darker than the darkest of Series III. By re-arranging these larvæ a few hours earlier on the 16th, and by selecting the least advanced out of a larger number, the black surroundings seem to have had the opportunity of producing their full effect; but it is also probable that these larvæ were more easily influenced in this direction.

B. The large cylinder (3·66 decimetres in internal diameter, and 1·34 decimetres in height), covered with a sheet of clear glass, already mentioned, was left in the same place on the floor, and in the evening of the 16th, when many larvæ were advanced in Stage II. upon the roof, a sheet of black paper was placed over part of the latter, on its less shaded side, while a sheet of white paper was placed over the more shaded part. As the roof was formed of clear transparent glass, there was every reason for believing that the same effect would be produced as if the roof had been really formed of black and white paper. All the larvæ pupated on the glass roof in three groups, and their colours were as follows :—

Group 1 was under the black paper and consisted of 25 pupæ,
of which . . . . . 5 were (1).
14 „ (2).
5 „ (3), dark.
1 was (3), with the gold of (4), but the pigment very dark.
—
25

Comparing these with the pupæ of A. division, the (1) were alike, the (2) of A. were a little darker; the dark (3) of A. were rather lighter, and the curious (3) differed in that from A. being more pink, that from B. more gold. There was very little difference between the dark (2) of A. and the (1) of B., which are not at all extreme, although the resemblance is chiefly due to the especial darkness of the (2). The amount of very dark pigment on the (3) of both A. and B. brings them very near the (2), but the prominent pink ground-tint is inconsistent with the latter degree.

Group 2 was under the black paper and consisted of 11 pupæ, of which 3 were (2).
8 „ (3), all dark.
—
11

A very uniform group. The (2) and dark (3) resemble those described above, and have the same relation to the A. division.

Group 3 was under the white paper, and consisted of 5 pupæ, of which all were (3), dark.

All exactly resembled those described above under the same degree.

No less than 22 out of the 41 pupæ were darker than any of Series III., and, omitting the four (2) of the latter, all the pupæ in Divisions A. and B., except the two lightest (3), are darker than any in the preceding series. There were pupæ among the dark (3) in Series III. with a greater amount of pigment than some of the dark (3) in the A. division, but the pigment in the latter was much darker in colour, although their pink ground-tint was also more distinct. It is, however, perhaps safer to exclude the five (3) of A. (IV.) from the above general statement as to the comparative darkness of these divisions and of Series III.

The comparison instituted above seems to show that these larvæ tend, as a whole, to produce darker pupæ than those of Series III. Such a conclusion shows how important it is in these experiments to keep the larvæ of the different companies carefully separate, for the error due to the different tendencies largely disappears in the experiments conducted within the limits of a single company. It appears that the white paper added when the preparatory period was far advanced nevertheless produced some slight effect, for none of the pupæ suspended under it were darker than dark (3), although on the more shady side of the cylinder.

C. Some of the larvæ from the other smaller cylinder, covered with "opal" glass, were (August 16, evening) placed in a cylinder (2·64 decimetres in internal diameter, and 9 centimetres in height) which had a roof of white glazed paper and a floor of ordinary white paper (common unruled white foolscap was always used for the white paper floors). This was placed in a good east light, about 5 feet from a large window. None of the larvæ in the former cylinder were suspended when the change was made, but many were prepared for suspension. The following results were obtained:—

Of 3 pupæ on the floor, but not fixed to the food-plant	2 were (3).
	1 was (4).
„ 6 pupæ in a small group suspended from the roof	all were (3), 1 of them dark (3).
„ 6 pupæ in another small group, suspended from the opposite side of the roof . .	1 was (2).
	5 were (3), 4 of them light, 1 with unusual gold, 3 with unusual pink.
„ 1 pupa, suspended to the side close to the last group, ...	was (3), dark.
— 16	

The results show clearly that the larvæ of this series were greatly influenced by white surroundings, for the above list is a very sharp contrast with either of the

divisions A. or B. At the same time, the influence was not nearly so strong as that of the same colour applied at the same time to Series III. (A. and B.). So that there is further support for the conclusion that the latter series tended more strongly towards the light forms than the larvæ of the company now being described.

D. Another lot of larvæ were taken (August 16, evening) from the smaller cylinder, those being especially selected which were as far removed as possible from suspension. They were placed in a cylinder (1·85 decimetres in internal diameter, and 8 centimetres in height) covered with a roof of gilt paper, which descended down the sides of the cylinder for a distance of about 1·6 centimetres. The floor was of white paper, and the conditions of light were similar to those of division C. The following results were obtained :—

Of 3 pupæ on the floor, but not fixed to the food-plant	2 were (3), 1 of them dark and 1 light.
	1 was (4), very golden.
„ 2 pupæ on the glass side, about halfway between the edge of the gilt paper and the floor, and close together (about 1·3 centimetres apart).	both were (3), 1 of them light, with unusual gold for (3).
1 pupa on the gilt roof, just above the two last,	was (3).
1 „ isolated on the roof	was (5), with plenty of gold, but not so extremely bright as is common.
Of 4 pupæ in a little group on the roof . . .	3 were (3), 1 more pinkish than usual, 1 rather more golden; but neither could be called light (3).
	1 was (2), very dark; almost a (1).

11

These results are very similar to the last, and suggest the same conclusions. In both there is some evidence for the effect of the larval bodies upon one another during the preparatory period.

E. (α) On the same evening (August 16) six larvæ, as far removed as possible from suspension, were chosen from the smaller cylinder and placed in an "opal" globe similar to that previously described (II., J.), with a glazed white paper roof and white paper floor. This was placed in a strong north light. When compared on the 22nd, the pupæ had the following arrangement and colour :—All the pupæ were suspended high above the food, and near the top of the globe upon its overhanging sides, although none of them were fixed to the roof.

The most isolated pupa was .	5·4 centimetres from the one nearest to it	and it was (4), very golden.
The pupa next in degree of isolation was	5·4 centimetres from the last, and 3·4 „ „ another pupa	It was light (3), unusually pink.
The pupa next in degree of isolation was	3·4 centimetres from the last, and 4·0 „ „ the nearest of the group.	It was light (3), unusually golden.
The 3 remaining pupæ were arranged in a group, at the angles of an isosceles triangle of which the sides were about 1·3 centimetre in length and the base about 2·1 centimetres.		They were all (3), 2 of them dark, although with pink colour distinct.

The effects produced by the white surroundings are, perhaps, rather stronger in this case, and are to be accounted for by the especial care with which the less mature larvæ were selected, so that the influence was of longer duration. The delicate susceptibility of the larvæ to the dark bodies of others near to them is extremely well shown in the difference between the three isolated pupæ and the three in a small group, and also in the difference between the most isolated pupa in the former number and the other two.

(β) At the same time six exactly similar larvæ were selected from the same cylinder, blinded, and placed in an "opal" globe, under precisely similar circumstances of food, light, &c. The results were :—

Of 3 pupæ lying on the floor, but not attached to the food, ...	2 were deformed, and were apparently 1 dark (3), 1 light (3).
	1 was perfect, and was . . . . . (3).
„ 2 suspended more than halfway up the sides of the globe and 1·05 decimetre apart, both were	(3).

In the relative results of (α) and (β) there is no sufficient reason for believing that the blinding produced any effect. Three of the blinded larvæ pupated in close proximity to the dark food, and therefore were in this respect under darker influences than the unblinded larvæ; but, on the other hand, the latter were more crowded, and so were under darker influences from another cause. Such an uncertainty, introduced into an experiment conducted with considerable care, chiefly induced me to separate the larvæ to a far greater extent, so as to diminish the errors due to both causes.

Thus 91 pupæ were obtained from Series IV., and very few of the larvæ died. It is, therefore, likely that I had obtained nearly the whole of a smallish company, and that none of them had previously left the nettle-bed. The results are open to the criticism upon Series III., but to a rather less extent, because, the larvæ being slightly less advanced, there was more opportunity for the influence of the coloured surroundings when the re-arrangement took place on the evening of August 16. The

demonstration of a somewhat different tendency in the larvæ of this company, as a whole, from those in the preceding company is of importance.

V.—The remnant of a company was found (August 22) on a very large nettle-bed close to South Hinçksey. From the extent over which the larvæ ranged, and the amount of nettle which had been eaten, it was evident that the company had been very large. Professor BURDON SANDERSON was with me at the time, and I spoke of the negative results of the blinding experiments, and asked his opinion as to the possible presence of the desired terminal organ in connection with the large and complex bristles which are present on the larvæ. As a result of our conversation, I determined to devote the greater part of these larvæ to the investigation of this question. I also wished, by the careful study of a few larvæ of this company, to ascertain as accurately as possible the duration of the period between the cessation of feeding and pupation, and of its constituent stages, especially II. and III. It was to be expected that Stage I. would be abnormally short, as the larvæ were confined in so limited a space.

The stock of larvæ were placed at 10.30 P.M., August 22, in the two cylinders mentioned in III., A., and III., B.; similarly arranged, with "opal" roofs and white-paper floors, but placed so as to receive a strong east light just beneath a large window. The experiments are described below under their respective divisions.

A. On the evening of August 22 a few larvæ were selected to form the subjects of experiment to test the above-mentioned suggestion as to whether the large branching spines contained any terminal organ which received impressions from coloured surfaces, and was thus the means of modifying the pupal colours. There are seven of these spines on most of the segments, and when they were snipped off the bases bled a little, and so it was clear that a subcuticular core was contained within them.

(α) Four larvæ, apparently still feeding, were selected, and their bristles were carefully snipped off, being cut as near to the base as was consistent with safety. These larvæ were placed in one of the two compartments of the gilt box already described, which faced a strong east light, standing about two feet from a large window. The history of the larvæ is given below :—

Aug. 22. 10.30 P.M. . .	4 shorn larvæ placed in compartment.	
„ 23. Morning . . .	Very little food eaten, and larvæ crawling up sides and on roof.	Stage I. of preparatory periods.
„ „ Early afternoon	Larvæ are crawling up sides and sitting on roof.	Stages I. and II. of preparatory periods.
„ „ 6 P.M.	2 suspended, and apparently another nearly ready.	Stages II. and III. of preparatory periods.
„ „ 9.30 P.M. . . .	2 more suspended.	
„ 24. 2.43 P.M. . . .	3 have pupated some little time: an hour or two. If the 3 larvæ ceased feeding about the time when they were placed in the compartment, it would make the whole preparatory period about 38–39 hours.	
„ „ 2.47–2.53 P.M. .	The last was seen to pupate at this time. The two larvæ which were last to enter Stage III. may be assumed to have become suspended about 7.45 P.M., Aug. 23, and hence Stage III. lasted 19 hours in one case and 17–18 hours in the other.	

Of the pupæ, two were in a corner of the roof, only 5 mm. apart, the third being 2·7 centimetres away from the one of the first-mentioned pupæ which was nearest to it, while the fourth was similarly 2·4 centimetres removed in another direction. Thus all four pupæ were suspended from the roof. Their colours were compared August 26, 4.15 P.M. :—

Of the 4 pupæ	1	was a very light (3) coming near a (4).
	2	were . . . . (4), very brilliantly golden.
	1	was. . . . . (5) „ „
	4	

(β) Five similar normal larvæ were at the same time placed in the other compartment of the gilt box. One was removed on the 24th (see the B. division), while still feeding; so that it is not necessary to describe it below. Their history is as follows :—

Aug. 22. 10.30 P.M. . .	5 normal larvæ placed in compartment.	
„ 23. Morning and afternoon.	The larvæ have been upon the roof most of the day, except one, which was removed on the 24th.	Stages I. and II. of the preparatory period.
„ „ 9.30 P.M. . . .	1 is suspended.	Stage III. of the preparatory period.
„ 24. 2 A.M.	Same.	
„ „ 8.35 A.M. . . .	3 suspended; but 1 has come down from the roof, and is wandering about actively.	
„ „ 2.43 P.M. . . .	1 has just pupated, and quite fresh. Assuming the larva to have ceased feeding about the time when it was placed in the box, the preparatory period would be about 40 hours, and if suspension took place about 7.45 P.M., Aug. 23 (as is most probable), Stage III. would have lasted 19 hours.	
„ „ 11.45 P.M. . .	2 more pupated, 1 recently, the other in the last few hours. If suspension began about 5.15 A.M., Aug. 24, the length of Stage III. would be about $18\frac{1}{2}$ hours in one case and a few hours less in the other.	
„ 25. 8.40 A.M . . .	The last has pupated some hours.	

All four pupæ were on the roof—three in a line along the right side, the anterior pupa 3·2 centimetres from the middle one, and the latter 2·2 centimetres from the posterior one. The fourth was on the other side of the roof, beside the vertical partition, and 9·5 centimetres away from the nearest of the others. Thus all were rather isolated, especially the last, but it was in a position which was on the whole less strongly illuminated. The colours were compared at the same time with the (α) sub-division :—

Of the 4 pupæ the	1 by the vertical partition was light	. (3).
The	3 others by the side of the box were all	(4), very golden, but not equal to the (4) pupæ of the shorn larvæ, except in one case, which is near a (5).
4		

The comparison between these two sets is, as far as it goes, completely destructive of the theory that the bristles contain the terminal organ which was sought for. The pupæ of the shorn larvæ are on the whole rather the more brilliant. Both sets show well the extremely powerful influence of the gilded surface upon the larvæ. There are also certain data from which we can arrive at a fairly accurate estimate of the length of the preparatory period and of Stage III.

B. On the morning of August 23 the two cylinders containing the stock of larvæ were examined, and it was seen that one larva had left the food, and was resting on the roof. This larva was joined by five others about 11 A.M. They were all sitting motionless (Stage II.), but when removed and placed on fresh food they would sometimes eat a little. At noon on the 23rd five larvæ were removed from the two "opal"-roofed cylinders, and were placed in separate cylinders of nearly the same height, and all of the same internal diameter, *i.e.*, 6·1 centimetres. Two of these larvæ (numbered 1 and 2) were among the six larvæ which had already entered Stage II. Each cylinder had a roof of white glazed paper, and two-thirds of the circumference was also surrounded (externally) by the same material, while the floor was of ordinary white paper. The cylinders were placed with the clear uncovered side facing a strong east light, about two feet from a large window. On the floor of each a single nettle-leaf was placed, which was renewed, if necessary, but always removed when the larva had ceased to feed. Thus the conditions appeared to be as nearly equal as it is possible to make them. The cylinders were numbered 1—6, and the larvæ were known by corresponding numbers. In comparing the results, it must be remembered that the larvæ numbered 1 and 2 were taken from the *roof* of the large cylinders in which the stock was kept, while those numbered 3, 4, and 5 were taken from the *food-plant,* Number 6 being added much later, and taken from the food-plant in one compartment of the gilt box previously described. The chief object of the experiment being to determine the lengths of the three stages of the period preparatory to pupation, the cylinders were frequently examined, the results being shown in a tabular form below :—

	Cylinder 1. 1·01 decim. high.	Cylinder 2. 1·06 decim. high.	Cylinder 3. 8·7 centim. high.	Cylinder 4. 8·0 centim. high.	Cylinder 5. 8·7 centim. high.	Cylinder 6. 8·0 centim. high.
Aug. 23. 12 noon	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	
1 P.M.	Nothing eaten	Nothing eaten	Still feeding	Still feeding	Still feeding	
6 P.M.	Gone to top of cylinder	Gone to top of cylinder	Gone to top of cylinder	Gone to top of cylinder	,, ,,	
9.30 P.M.	No change	No change	No change	No change	Gone to top of cylinder	
11 P.M.	,, ,,	,, ,,	,, ,,	,, ,,	No change	
Aug. 24, 1.10 A.M.	Suspended and placed in darkness 1.30 A.M.	,, ,,	,, ,,	,, ,,	,, ,,	
2.50 A.M.	Not examined	Suspended, and probably earlier, but unnoticed	,, ,,	,, ,,	,, ,,	
8.45 A.M.	Still suspended	Still suspended	,, ,,	8.35 A.M., suspended and placed in darkness	8.35 A.M., no change	9.15 A.M., experiment began; 12 noon, gone up cylinder.
2.53 P.M.	,, ,,	,, ,,	2.43 P.M., suspended	2.50 P.M., still suspended	2.43 P.M., suspended; at 2.50 P.M., placed in darkness	2.43 P.M., suspended.
5.35 P.M.	Not examined	Just pupated, still moist	,, ,,	Not examined	Not examined	,, ,,
11.30 P.M.	Just pupated, light green	..	11.35 P.M., still suspended	Still suspended	Still suspended	,, ,,
Aug. 25. 8.40 A.M.	..	..	Recently pupated, still green	8.50 A.M., pupated some hours, and darkened	8.50 A.M., pupated lately	Recently pupated, still green.
Results . . .	Light (3)	Light (3)	(3) Very little gold	(3) Normal gold	(3) Very little gold	Very light (3), with rather more gold than usual.

From the data the approximate duration of the respective stages was estimated by taking the mean of the times between which the beginnings and ends of the stages occurred, the following results being obtained :—

	Stages I. and II.	Stage III.	The whole preparatory period.
Larva 1	Incomplete	About 23 hrs.	Incomplete
„ 2	Incomplete	Uncertain.	Incomplete
„ 3	About $20\frac{1}{4}$ hrs.	About $20\frac{1}{4}$ hrs.	About $40\frac{1}{2}$ hrs. (very nearly correct)
„ 4	„ $14\frac{1}{4}$ „	„ $22\frac{1}{2}$ „	About $36\frac{3}{4}$ hrs.
„ 5	„ 16 „	„ $20\frac{1}{4}$ „	About $36\frac{1}{4}$ hrs. (very nearly correct)
„ 6	Incomplete	„ 19 „	Incomplete
Averages	Average of the 3 instances $16\frac{5}{6}$ hrs.	Average of the 5 instances 21 hrs.	Average of the 3 instances $37\frac{5}{6}$ hrs.

Comparing these averages with the estimates in Division A. of this series, the length of Stage III. is here rather longer, and that of the whole period slightly shorter, but without much difference. It is to be noted that in three cases (Nos. 1, 4, and 5) Stage III. was passed in the dark, and that the duration of the stage was rather longer than in the other larvæ (except in one case, in which the length was the same as that of the shortest of the stages passed in the dark). If the stages were somewhat protracted by this treatment, of course the whole preparatory period would be correspondingly lengthened. Evidence in favour of such protraction will be found in some of the later experiments upon this species, and also in the case of the Pieridæ.*

The exceptionally short duration assigned to Stages I. and II. in Larva 4 may be partially explained by supposing that the stage really began very soon after 1 P.M. on August 23 (instead of at 3.30 P.M., and thus halfway between 1 P.M. and 6 P.M.), and that it was thus about two hours longer. Such a supposition is rendered probable by a comparison of the times of pupation of Larvæ 3 and 4.

In such small cylinders the larvæ wandered very little before fixing on the position in which to suspend themselves, and therefore Stage I. was reduced to a minimum.

As to the colours of the pupæ, there was very great uniformity, Pupa 6 being the lightest, then Pupæ 1 and 2, and then, after an equal interval, Nos. 3, 4, and 5 ; but the whole of the difference being comprised in the slight interval between normal (3) and very light (3). Thus the white-paper back-ground produced much less effect than the gilt back-ground in Division A., and the lightest of these pupæ, 6, had already passed Stage I. and much of Stage II. in the gilt box. The removal of three of the larvæ into darkness during Stage III. produced no apparent effect, but the numbers

* This probable effect of darkness appeared to be so important that I experimented upon 44 larvæ during the past summer (1887) with the object of testing the above-mentioned conclusion. The larvæ, placed in a strong light, were surrounded in some cases by gilt and in others by tin surfaces ; those in the dark being surrounded by black paper. Without giving the details of the experiment, I may say that its results conclusively proved that darkness does considerably protract the preparatory period. There did not appear, however, to be any evidence for the supposition that the gilded pupæ pass through a shorter preparatory period than those which are less brilliant, when both are equally exposed to light.—September 10, 1887.

employed, together with their results, are insufficient evidence from which to conclude that the larvæ are not sensitive during this stage, although it appears almost certain that the earlier Stage II. is the time of chief susceptibility to surrounding influences. It will be shown that the larva can hardly be susceptible after the first part of Stage III., and it is very likely that in two out of three instances the most important and earliest hours had already elapsed when the larvæ were transferred; this suggestion cannot, however, explain the case of No. 1, for this larva must have been shifted very soon after the beginning of suspension.

C. Another division of larvæ was taken from the "opal"-roofed cylinders and made use of in order to test whether the spines contain the terminal organ which receives impressions from coloured surroundings. Nine larvæ were carefully shorn of their bristles on the evening of August 23, and two of them were left in one of the above-described "opal"-covered cylinders as they had quitted the food and were resting on its roof, while the other seven, being rather less advanced, were placed one in each of seven "opal" globes similar to those previously described, except that a glazed white-paper roof was, in nearly all instances, fixed to the smaller opening, while the edge of the larger opening of the globe rested on a floor of ordinary white paper, upon which never more than two leaves were placed at one time, renewed when necessary, and removed when it was obvious that the larva had ceased to feed. Seven exactly similar, but normal, larvæ were placed in seven other globes, all conditions being identical, except the following unimportant differences, which were compensated as far as possible:—The globe numbered 1 below was lower and smaller than the others; that numbered 2 was turned with the larger end uppermost and covered by the roof; 5 and 13 had been broken and were mended with white glazed paper, so that there was more surface of paper in 5 than in the others, the loose piece in 13 being merely retained in its place by paper glued on to the outside of the globe. The 14 globes were arranged on two shelves, one above the other, in a strong north light close to a large window, and the two series of larvæ were placed in alternate globes: the shorn larvæ occupying globes with the even numbers 2–14, the others occupying those with the odd numbers 1–13; and Globes 1–7 occupied the upper shelf, 8–14 being below. By this arrangement all possible errors due to differences of illumination were compensated, for as soon as a larva had ascended the side or had suspended itself the globe was always turned round, so that the larva was next to the window. Such an experiment was certain to yield useful results, apart from the main question of a possible terminal organ in the bristles; for, by noting the results of frequent examination, it was possible to gain further knowledge of the three stages of the preparatory period; and, as in the larvæ of Division B., the action of white surroundings upon the larvæ was tested in the most satisfactory way by the elimination of the sources of error present in the otherwise similar experiments of the preceding series. The results of examination are expressed in a tabular form below. The larvæ numbered 4 and 5 died, and are not further alluded to.

	Globe 1. Normal.	Globe 2. Shorn.	Globe 3. Normal.	Globe 6. Shorn.	Globe 7. Normal.	Globe 8. Shorn.	Globe 9. Normal.	Globe 10. Shorn.	Globe 11. Normal.	Globe 12. Shorn.	Globe 13. Normal.	Globe 14. Shorn.
Aug. 23, 10.15 P.M.	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began	Experiment began
Aug. 24, 9.25 A.M.	Very little eaten; gone up globe	Still feeding	A little eaten; suspended	Little eaten	Nothing eaten; suspended	Still feeding	Much eaten; gone up	Still feeding	Still feeding	Little eaten; gone up	Still feeding	Still feeding
3 P.M.	Suspended	Gone up globe; spun boss	„	Gone up	„	Gone up	Came down	„	„	Suspended	„	„
7.54 P.M.	„	Suspended	„	Suspended	„	„	Gone up	„	„	„	Gone up	Gone up
11.35 P.M.	„	„	Just pupated; still green	„	Just pupated; still green	„	Suspended	Gone up	„	„	„	„
Aug. 25, 8.40 A.M.	Pupated; darkened	„	..	„	..	Suspended	„	„	„	„	„	Suspended
6.55 P.M.	..	Pupated; darkened	..	Pupated; darkened	..	„	Pupated; darkened	Suspended	„	Pupated; darkened	Suspended	Just pupated; still green
10.40 P.M.	..	..	..	..	..	Pupated; partially darkened	..	„	„	..	„	..
Aug. 26, 10 A.M.	..	..	..	..	..	..	..	Just pupated; still green	Pupated at much later date.	..	Pupated; darkened	..
Position of pupæ	Side of globe, ⅔ up	Side of globe, just below roof	Side, rather over ½ up	Side, 3·8 centims. up	Side, 3·8 centims. up	Side, ⅓ up	Side, ⅓ up	Side, ⅓ up	Side; height unnoted	Side, rather over ½ up	Side, rather over ½ up	Side, ⅔ up
Colour of pupæ, Aug. 26, 3.30 P.M.	(4) Much bright gold	(4) Much bright gold	(4) Much bright gold	Light (3)	(3)	Light (3)	(3)	(3)	Very light (3) (compared Aug. 29)	Light (3)	(3)	(3)

From this Table the duration of the stages can be approximately estimated as follows :—

	Stages I. and II.	Stage III.	The whole period.
	hrs. mins.	hrs. mins.	hrs. mins.
1	About 8 22	About 15 50	About 24 12
2	„ 5 15	„ 20 20	„ 25 35
3	„ 5 0	„ 19 10	„ 24 0
6	„ 5 15	„ 20 20	„ 25 35
7	..	„ 19 10	..
8	„ 15 50	„ 17 0	„ 32 45
9	„ 4 18	„ 16 0	„ 20 20
10	„ 16 0	„ 19 45	„ 35 45
12	„ 8 22	„ 25 35	„ 34 0
13	„ 20 20	„ 14 30	„ 35 0
14	„ 10 35	„ 14 30	„ 25 0

The comparison between these pupæ and those of Division B. was most carefully carried out, and the two divisions were compared together. The method adopted in comparing the results of all careful experiments was as follows. The pupæ were arranged side by side on a sheet of white paper, so that all their ventral surfaces were illuminated by a strong east light which fell upon all the pupæ at the same angle ; having thus decided upon their arrangement in the order of relative darkness or amount of gilding, they were all turned over, or the paper turned round so that the dorsal surfaces were illuminated in the same manner ; and the previous order was confirmed or modified, as the case might be ; but on very nearly all occasions the two surfaces gave corresponding results, and the only exceptions were when the differences were extremely slight. The results of the experiment tabulated above agree with those of Division A. in being destructive of the supposition that the desired *terminal organ exists in the larval bristles.* The figures seem to be very conclusive on this point. As to the length of the stages and of the preparatory period brought out by the above Table, there is little doubt that the larvæ had in nearly all cases begun the period before being placed in the globes, and that the estimated length of the whole period and that of the two initial stages is far too short in nearly all cases. Further evidence of this suggestion will be adduced in the next division (D.). It is probable that the estimated length of the last stage (III.) is, on the whole, about normal, as the above 11 instances give an average length of 18 hours $16\frac{4}{11}$ min. for this stage. A few of the larvæ seem to have passed through periods of about normal length.

D. Another small number of larvæ were also made use of to test the presence of terminal organs in the bristles. They were divided into two subdivisions as before:—

(α) Of the nine larvæ which were shorn on the evening of August 23, two had already quitted the food and were upon the roof or side. These were left in the lower of the two " opal "-covered cylinders with white-paper floors (described in III., A. and B.), the food was removed, and another larva was added which had been shorn on the

night of August 22 with those of Division A. in this series. The history of the larvæ is given below :—

Aug. 23, evening (10.15 P.M.)	2 larvæ on roof: the 3rd (last added) on floor.	
Aug. 24, 8.35 A.M.	The last added suspended from side : others still on roof.	Larva 1 may have been suspended about 3.30 A.M.
,, 9.15 A.M.	Another suspended : the other has come down again and wandering.	Larva 2 suspended about 9 A.M. ,, 3 may have come down about 8.55 A.M.
,, 12 noon	Last still wandering.	
,, 2.43 P.M.	It has gone up side, and is resting on it	Larva 3 may have gone up about 1.21 P.M.
,, 5.35 P.M.	Suspended	,, 3 suspended about 4 P.M.
,, 11.30 P.M.	Suspended.	
Aug. 25, 8.40 A.M.	The first two larvæ have pupated some hours.	1 and 2 may have pupated about 4 A.M. Stage III. in 1 was about $24\frac{1}{2}$ hours. ,, in 2 was about 19 hours.
,, 8.50 A.M.	The last larva has pupated in the last 10 minutes.	Hence Stage III. occupied almost exactly $16\frac{3}{4}$ hours in Larva 3.

Two of the pupæ were near together, towards the top of the side of the cylinder farthest from the window, and 1·7 centimetres apart ; the third was on the roof.

Of the 3 pupæ the 1 on the roof was a darkish . . . . . (3).
Of the 2 ,, side 1 (the larva last added) was . . . (4), without much gold.
— 1, the last to pupate, was a very light (3).
3

(β) In the other, rather higher, cylinder two similar normal larvæ were left.

Aug. 24, 8.35 A.M.	Both suspended	They may have suspended about 3.30 A.M.
,, 2.55 P.M.	1 has pupated since 2.43 P.M.	Pupation at 2.50 P.M. Hence Stage III. would be about 11 hours.
,, 6.5 P.M.	The 2nd has pupated since 5.35 P.M. . .	Pupation at 6.45 P.M. Hence Stage III. would be about $15\frac{1}{4}$ hours.

The pupæ were both on the roof and 1·5 centimetres apart. The two pupæ were both very light (3).

This experiment confirms the conclusion derived from the others : that the spines do not contain any organ essential to the larval sensitiveness to colour influences. It is also seen, as in the other divisions, that the white surroundings are much less powerful than the gilt surroundings in the direction of producing the gilded appearance on the pupæ. There are also some additional data for the estimate of the duration of Stage III., and in the case of Larva 3 in the (α) subdivision the stage has been defined with practical accuracy ($16\frac{3}{4}$ hours). In the other larvæ there are possibilities of wide differences from the times at which it is assumed that suspension began or pupation took place, and therefore less importance is to be attached to the estimates. The preparatory period had in all cases commenced before the larvæ were periodically examined, but in Larva 3, subdivision (α), $34\frac{1}{2}$ hours elapsed after the examination began. This larva was evidently in Stage II. at the commencement of the

investigation, but (probably on account of disturbance) it again wandered for a short time, passing through another Stage I. of about $4\frac{1}{2}$ hours, and then again an exceedingly short Stage II. of only a little over $2\frac{1}{2}$ hours, the final stage being, perhaps, a little less than normal. These facts throw further light on the stages of certain larvæ which appear to be most abnormally short, and seem at first sight to show that it is impossible to obtain an average duration for the stages which would be of any practical value for the investigation of any particular larva. Such a conclusion might be arrived at by comparing the exceedingly divergent estimates of Stages I. and II. in Divisions B. and C. of this series, and also by comparing the estimated lengths of the total periods in these two divisions respectively. But the above-described larva shows us how after disturbance the whole preparatory period may begin again and all its stages may be passed through, but that under these circumstances the stages, and especially the two initial ones, are considerably abbreviated. It has been remarked above that the larva may even feed again after disturbance and before the recommencement of Stage I., so that the resemblance of the abbreviated period to one of normal length may be very close. And there is independent evidence for this explanation of the abnormal shortness of the stages and periods in Division C., for in the introductory sentences of Division B. it is shown that six larvæ were already in Stage II. on the morning of the 23rd, and of these only two were made use of for Division B. It is certain that many others had also entered this stage when the larvæ were shorn, and the experiments described in Division C. began in the evening of the same day, although disturbance had led the larvæ to quit the roof and in many cases to feed again both before and after they had been placed in the globes. Further data will confirm this explanation of the apparent abnormality in Division C.

Before proceeding to the next series, it will be advisable to recapitulate the results of the experiments upon the shorn larvæ, and then the subject need not be further alluded to.

Division.	Surroundings.	Degrees of colour in pupæ of shorn larvæ.								Degrees of colour in pupæ of normal larvæ.							
		1	2	Dark 3	3	Light 3	4	5		1	2	Dark 3	3	Light 3	4	5	
A.	Gilt box	..	..	..	..	1	2	1		..	..	..	..	1	3	..	
C.	White "opal" globes	..	..	..	2	3	1	..		..	..	..	3	1	2	..	
D.	"Opal" covered cylinders	..	..	1	..	1	1	..		..	..	..	..	2	..	..	
Totals.	..	..	..	1	2	5	4	1	= 13	..	..	..	3	4	5	..	= 12

The above Table shows how completely the suggestion was negatived by the experiments; it also indicates that the gilt surroundings were much more powerful

than the white, and this is further confirmed if the results of Division B. be taken into consideration. I also noted that when the pupæ produced respectively by these two surroundings were equally brilliant, and were therefore placed in the same degree of colour, those which had been influenced by the gilt surface were of a much deeper, truer, gold-colour than the others, which were often silvery-white. I had abundant opportunity of confirming this observation on subsequent occasions. The total number of pupæ obtained from this division was 31.

VI.—Another series of larvæ were also obtained from the same large nettle-bed near South Hincksey, August 22, but they were on a different part of the bed from those of the last series, and were also much less advanced. They probably constituted the whole of a very small company.

After the negative results of the experiments upon the bristles I determined to renew the blinding experiments, making use of all the precautions which had been observed in the last series.

A. In this experiment the two "opal"-covered cylinders, already frequently alluded to, were made use of. The history of the experiment is given below in a tabular form:—

Dates, &c.	(α) 12 normal larvæ in opal-covered cylinder with white-paper floor.	(β) 12 blinded larvæ in a similar cylinder.
Aug. 25, 10.30 P.M.	Larvæ placed in cylinder	Larvæ blinded and placed in cylinder.
Aug. 26, 9.35 A.M.	. . . . .	3 suspended; the remaining 9 reblinded; only 2 on food-plant; rest preparing for suspension.
„ 12.10 P.M.	Only 2 on food-plant; rest getting ready for suspension	No change.
„ 12.40 P.M.	1 of those on food-plant is really suspended from it; not noticed previously	4 suspended; only 1 on food-plant. (1 about 12.25 P.M.)
„ 3.30 P.M.	2 suspended altogether; but all others ready. (1 about 2 P.M.)	7 suspended; only 1 on food-plant. (3 about 2 P.M.)
„ 5.30 P.M.	2 suspended altogether; but all others ready. (1 about 2 P.M.)	7 suspended; only 1 on food plant. (3 about 2 P.M.)
„ 7.50 P.M.	6 suspended altogether; but all others ready. (4 about 6.40 P.M.)	9 suspended; only 1 on food-plant. (2 about 6.40 P.M.)
„ 9.10 P.M.	10 suspended altogether; but all others ready. (4 about 8.30 P.M.)	10 suspended; only 1 on food-plant. (1 about 8.30 P.M.)
„ 10.45 P.M.	. . . . .	1 pupated, among a group on the side, quite recently; green and still very soft; 9 suspended, 1 ready for pupation on floor, and 1 still feeding.
„ 10.55 P.M.	11 suspended (1 about 10.50 P.M.)	
„ 11.25 P.M.	No change	No change.
Aug. 27, 9.40 A.M.	2 pupated an hour or two; all suspended. (Hence Stage III. about 19 hours; this must be nearly correct for 1 of the pupæ)	8 have pupated; 1 very recently (Stage III. about 15 hours) and 2 an hour or two (Stage III. about 18 hours); the others many hours; among latter is the one lying on the floor; the last larva to feed is now ascending side.
„ 12 NOON	5 pupated altogether. (3 about 11 A.M., and Stage III. about 16 hours)	9 have pupated (about 11 A.M., Stage III., 16¼ hours about); the last larva still wandering.
„ 1.15 P.M.	10 pupated altogether (5 about 12.37 P.M., and Stage III. about 16 hours, in the case of 4 pupæ, and not very different with the 5th)	The last larva has gone up to roof. (12.37 P.M. about; Stage I. at least 3 hours.)
„ 2.12 P.M.	10 pupated altogether	10 have pupated altogether. (1.45 P.M. about; Stage III. about 17¼ hours.)
„ 4.7 P.M.	11 pupated altogether. (1 pupated about 3.10 P.M., and Stage III. about 16 hours 20 minutes)	11 have pupated altogether.
„ 9.30 P.M.	All 12 have now pupated	The last larva is suspended. (About 6.45 P.M.; Stage II. about 6 hours.)
„ 10.58 P.M.	. . . . .	The last larva is suspended.
Aug. 28, 10 A.M.	. . . . .	The last larva has now pupated quite recently. (Thus Stage III. about 15 hours, and the whole period only about 24 hours since 9.40 A.M., but Stage I. may have begun much earlier.)
Aug. 29. Comparison of results	8 on roof, much crowded, and of these 1 pupa was (2), darkish. 2 pupæ were dark (3) 3 „ „ (3) 2 „ „ light (3) 2 also on roof, close together, but a long distance from rest, were both light (3) 1 on side (clear glass) and isolated, very dark (3) 1 on floor attached to food, but not in — shadow at all, was (4), normal, 12 with large amount of gold.	6 very crowded on side (clear glass) towards light: these were 2 very dark (3), almost (2). 4 . . . (3), 1 of them rather lightish, but not a light (3). 1 on side, isolated, towards light, (4), very pink, with rather small amount of gold. 1 on floor, isolated, very light (3). 4 on roof, and isolated, were — 1 (3), 12 2 (4), golden. 1 (5), normal.

Thus the blinded larvæ were, on the whole, more golden than the others, but of course no significance can be attributed to this. From the frequently recurring examination of the larvæ it is possible to form a very accurate estimate of the duration of Stage III., although the whole period and the other stages cannot be similarly made out from the notes. The different estimates are as follows :—

					hrs.	min.
In 2	larvæ	the duration of	Stage III.	is estimated at	15	0
7	,,	,,	,,	,,	16	0
1	,,	,,	,,	,,	16¼	0
1	,,	,,	,,	,,	16	20
1	,,	,,	,,	,,	17¼	0
2	,,	,,	,,	,,	18	0
2	,,	,,	,,	,,	19	0
16	larvæ.			Average	16	37

Thus estimates were obtained for this stage in 16 larvæ out of 24, and in many cases the estimates must have been very nearly accurate. Furthermore, the extremes only differ from each other by four hours.

In addition to the above estimates, there is some insight into the other stages of a single larva in (β) subdivision, and in this instance it is shown that Stage I. must have occupied at least three hours, and Stage II. about six hours.

The experiment also shows the effect of white surroundings.

B. The globes already described in Series V. were made use of for this experiment, all the arrangements being identical, except that Nos. 5 and 11 were omitted (as they still contained larvæ of the previous series). The larvæ in the globes were alternately blinded and normal, two larvæ being placed in each globe, except two (numbered 13 and 14), for it was thought that if allowance were made for their position this number might be safely included without introducing error. Notes were not taken with sufficient frequency to render it possible to estimate the length of the stages of the preparatory period, and therefore it is unnecessary to give more than the results of the experiments. The larvæ were introduced into the globes on August 26, 10.30–11 A.M. :—

	Date when found pupated.	Position in globe.	Comparison of colours August 29.
Globe 1. Normal.	Both on Aug. 27, 9.30 P.M.	Both $\frac{3}{4}$ up and on opposite sides	Both light (3).
Globe 2. Blinded.	One „ „ „	Both low down and about $\frac{1}{4}$-circumference between them. The higher pupa $\frac{1}{4}$ up	One very dark (3).
	One later		One very light (3).
3. N.	One on Aug. 27, 9.30 P.M.	One on white-paper floor .	(3), with dark pigment, but prominent pink tinge.
	One „ „ 9.50 A.M.	One $\frac{2}{3}$ up	(3).
4. B.	Both „ „ 9.30 P.M.	One suspended from paper roof	(4), pink rather than golden.
		One on floor (deformed) .	Apparently light (3).
6. N.	One „ „ „	One $\frac{2}{3}$ up	Very light (3).
	One „ „ 9.50 A.M.	One on floor	(4); not much gold, very pink, great absence of pigment.
7. B.	Both „ „ 9.30 P.M.	Both $\frac{1}{2}$ up and 3·2 cm. apart	Both (4); not much gold, very pink, great absence of pigment.
8. N.	One „ „ „	Both $\frac{3}{4}$ up and 1·2 cm. apart	One dark (3), one (3).
	One „ „ 9.50 A.M.		
9. B.	One „ „ 9.30 P.M.	One $\frac{1}{3}$ up	Light (3).
	One later	One on floor (deformed) .	Apparently light (3).
10. N.	Both on Aug. 27, 9.30 P.M.	Both rather over $\frac{1}{2}$ up and 1·3 cm. apart	One darkish (3). One (3).
12. B.	One „ „ „	One fell down, probably $\frac{1}{3}$ up	Very dark (3).
	One „ „ 9.50 A.M.	One on top, fixed to globe rim	Very dark (3).
13. N.	One (only) on Aug. 27, 9.30 P.M.	$\frac{1}{2}$ up	Light (3).
14. B.	One „ „ 9.50 A.M.	One on floor (deformed) .	(4), normal pink and gold.

As in all the other cases in which the larvæ were blinded, this experiment yields negative results, and subsequent to this date blinding experiments were not further pursued (except in Series VIII. and under other conditions). The effect of proximity is doubtless seen in the darkish colour of the pupæ in Globes 8 and 10.

C. In an examination and re-arrangement of the stock of larvæ (in a large clear glass cylinder), August 26, three were found suspended from the food-plant and much shaded, and were transferred to the gilt compartmented box, while three more were suspended from the clear glass roof, which was placed over a black cylinder and covered with black paper (on its upper free surface). Thus the experiment was intended as a further test of the larval susceptibility during Stage III.

The experiment was conducted as follows:—

Dates, &c.	(α) 3 larvæ transferred to gilt box for all or part of Stage III.	(β) 3 larvæ transferred to black cylinder for all or part of Stage III.
Aug. 26, 10.55 A.M.	3 suspended larvæ transferred from food-plant to gilt box	3 larvæ, suspended to a clear glass roof, transferred to black cylinder.
„ 4.30 P.M.	Still suspended	Still suspended.
„ 5.30 P.M.	1 pupating. (Thus $6\frac{1}{2}$ hours of Stage III. were passed in the box.)	„ „
„ 7.50 P.M.	No change	„ „
„ 9.10 P.M.	Another pupated about 8.30 P.M. (Thus about $10\frac{1}{2}$ hours of Stage III. were passed in the box.)	„ „
„ 11.30 P.M.	No change	„ „
Aug. 27, 9.40 A.M..	Last pupated many hours, about 4.35 A.M. (Thus about $17\frac{3}{4}$ hours of Stage III. were passed in the box.)	All 3 pupated many hours, about 4.35 A.M. (Thus about $17\frac{3}{4}$ hours were passed in the dark.)
Aug. 29. Results of comparison together and with all examined on this date.	All 3 pupæ were (3), one of them a little darkish, and none quite so light as the (3) in the dark cylinder, but very little difference between any of the (3) in gilt box or dark cylinder.	1 of the 3 pupæ was a dark (2). 1 „ „ (3). 1 „ „ lightish (3), – rather more gold than usual. 3

Comparison of the dates shows that two of the larvæ in the box cannot have passed the first and presumably the sensitive part of Stage III. under the influence of gilt surroundings, and it is by no means certain that the third larva pupated at a time near the hour which is selected, for the limits were very widely separated, and the estimate therefore becomes exceedingly rough. The three larvæ in darkness all pupated in this wide interval of time, but here it becomes more probable that one or more of them passed almost the whole of Stage III. under the new conditions, and we find that one of them is very dark. It must be remembered that the latter larvæ had been previously exposed to plenty of light, and were not among dark surroundings, whereas the former were much shaded and among the dark leaves of a large amount of food-plant. The experiment, as far as it goes, certainly favours the view that the larvæ are sensitive during part of Stage III., although, standing alone, it would be totally insufficient as evidence. It is noteworthy that the larva in darkness was the only (2), except one, obtained in the whole of this series.

Thus 52 pupæ were obtained in this series.

VII.—A small number of larvæ (12), the remnant of a company, were found August 26 on a nettle-bed in Binsey churchyard, and four others, certainly belonging to the same company, were found on the church itself in the prepara tory period. The negative results obtained with the shorn larvæ induced me to again attempt the blinding experiments with these larvæ also, for the results of the last series had not been obtained.

A. The 12 larvæ were made use of for this experiment, of which an account is given below:—

Dates, &c.	(α) Blinded larvæ.	(β) Unblinded larvæ.
Aug. 26, 9.35 P.M. .	6 larvæ blinded and placed in left compartment of the gilt box already described	6 normal larvæ placed in the right compartment.
„ 10.55 P.M. .	No change	2 on roof, resting, and another wandering (Stage I. ended about 10.15 P.M.).
„ 11.25 P.M. .	„	4 on roof, resting, and 1 wandering (Stage I. of 2 more ended about 11.10 P.M.).
Aug. 27, 9.40 A.M. .	5 on sides or roof, 1 feeding	4 still on roof, resting; 1 on back, 1 on food-plant.
„ 12 NOON .	4 on roof, 1 on side	5 on roof (Stage I. of 1 more ended about 10.50 A.M.).
„ 1.15 P.M. .	6 on roof (1 changed position later) . .	2 suspended (about 12.37 P.M.), 1 on food-plant.
„ 4.7 P.M. .	4 suspended (about 2.40 P.M.)	5 suspended; 1 of them is the larva on the food-plant. (3 about 2.40 P.M.)
„ 5.55 P.M. .	5 suspended (about 5 P.M.)	All 6 suspended (1 about 5 P.M.).
„ 10.58 P.M. .	5 suspended	All 6 suspended.
Aug. 28, 10 A.M. .	5 pupated some few hours (about 7 A.M.), the 6th died. Hence Stage III. lasted about 16 hours in the case of 4 larvæ, and about 14 hours in the case of the 5th	All pupated some few hours (about 7 A.M.). Results will be given below.
Results, pupæ compared Aug. 29.	1 pupa, isolated on side, was very light (3), nearly (4) 4 near together on roof, but not crowded; of these 1 external pupa is (4), normal. The other, external, is light (3). The 2 internal ones are light (3). 5 The whole period may have lasted about 30 hours, but the position of the commencement cannot be estimated with any accuracy.	4 pupæ were arranged in an irregular (not crowded) line along one side of roof: of these 3 were (4), normal. 1 was very light (3). pink, not unusual gold. 1 was isolated on other side of roof, and was . . . (5), typical. 1 was hanging from food-plant, and was . . . . (4). 6

Although the (α) subdivisions are not so brilliant as the (β), they are none of them dark pupæ, and there is nothing in the difference which can justify the theory that the ocelli are the larval organs influenced by the surrounding colours in the preparatory period.

The experiment also throws much light on the duration of the preparatory period and its stages. In the (α) subdivision the process of blinding probably disturbed the larvæ and prevented the normal beginning of Stage I., until it was too late to observe it, and hence the length of Stage III. is alone obtained with any degree of accuracy from these larvæ. But the normal larvæ yielded far more precise results, which are shown below:—

(1) The two larvæ first suspended on roof	Aug. 26, 9.35 P.M.	Stage I. About 40 min., but it may have begun before 8, but not before 7 P.M., when the larvæ were found	Aug. 26, 10.15 P.M., almost exact	Stage II. 14 hrs. 22 min.	Aug. 27, 12.37 P.M., almost exact	Stage III. About 18½ hrs.	Aug. 28, 7 A.M., correct to 2 hrs. at the outside
		The whole preparatory period about 33½ hrs. long: 36 hrs. if the disturbance of capture caused Stage I. to begin at once.					
(2) The second lot of two larvæ to suspend from the roof	Aug. 26, 9.35 P.M.	Stage I. Certainly the whole time in the box, 1¾ hrs., and probably longer	Aug. 26, 11.10 P.M., almost exact	Stage II. 15½ hrs. . . .	Aug. 27, 2.40 P.M., must be correct to 1½ hrs.	Stage III. About 16 hrs. 20 min.	Aug. 28, 7 A.M., correct to 2 hrs. at the outside
		As above; the whole period 33½–36 hrs.					
(3) The fifth larva to suspend from the roof	Aug. 26, 10.15 P.M., but probably earlier	Stage I. 12½ hrs. . . .	Aug. 27, 10.50 A.M., must be correct to 1¼ hrs.	Stage II. 6 hrs. 10 min.	Aug. 27, 5 P.M., almost exact	Stage III. About 14 hrs.	Aug. 28, 7 A.M., as above
		The whole period about 33 hrs., but probably longer.					
(4) The larva suspended on food-plant	The first stages cannot be estimated, because when a larva is on the food-plant it is assumed to be feeding.				Aug. 27, 2.40 P.M., must be correct to 1½ hrs.	Stage III. About 16 hrs. 20 min.	Aug. 28, 7 A.M., as above

From the above Table it is possible to gain a very correct estimate of the duration of the stages and of the whole period: Stage III. is seen to be fairly constant in length, but the others very irregular. The boundaries of the different stages are fixed with great exactness in nearly all cases, owing to the number of the observations and the fact that the experiment began about two-and-a-half hours after the larvæ were taken from their food-plant. I think that this Table gives the duration of the different stages more completely than they can be found in any of the other series.

B. The four larvæ found motionless, but not suspended (Stage II.), upon the porch of Binsey church were made use of in a transference experiment; the three found upon grey stone (light) being placed in black surroundings, and the one found upon the oak door (dark) being placed in white surroundings. Between their capture and subjection to these influences they were kept in ordinary chip-boxes of light wood, partially transparent. The experiment is described below:—

Dates, &c.	(α) The larvæ found on light stone.	(β) The larvæ found on dark oak.
Aug. 26, 7 P.M. . .	Found on stone; kept in chip-box till put in dark cylinder	Found on oak; kept in chip-box till put in white cylinder.
„ 10.45 P.M. .	Placed in small cylinder covered with 1 layer of black tissue-paper and black floor	Kept in chip-box till put in white cylinder.
„ 11.30 P.M. .	No change	Placed in small cylinder covered with white paper.
Aug. 27, 9.40 A.M. .	All suspended from roof	Suspended from roof.
„ 9.30 P.M. .	„ „ „	„ „
„ 10.58 P.M.	2 just pupated	„ „
Aug. 28, 10 A.M. .	The last pupated very many hours . .	Pupated very many hours.
Results, pupæ compared Aug. 29.	Of the 3 pupæ suspended from roof, 1 was light (3). 2 were . (3). — 3	The 1 pupa on roof was (3).

There are not sufficient data from which to make estimates of the length of the stages.

There was extremely little difference between the pupæ, and the results agree well with those of other transference experiments, for it is probable that the pupal colour was in both (α) and (β) largely influenced by the fact that Stage II. had been passed (at any rate in part) upon surroundings which, in each case, tended in a different direction from the environment to which the pupæ were exposed in Stage III.

Thus 15 pupæ were obtained in this series.

VIII.—A. A few mature larvæ (16), the remnant of a company, were found August 28 in a field bordering the canal by Port Meadow. These were made use of in a single experiment to further confirm the negative results of former blinding experiments. In this instance the blinded and unblinded larvæ were both put in exactly similar *dark* cylinders, with black roofs and floors. This was to settle two questions: (1) whether the blinding, although insufficient to alter the influence of gilt or white surroundings, might possibly augment the influence of black surroundings; (2) whether the presence of the opaque varnish on the ocelli could possibly act itself as a stimulus, producing effects similar to the stimulus of bright surfaces.

The latter suggestion appeared to be extremely improbable, but the whole investigation seemed to be so difficult, and the results often so contrary to expectation, that it was thought better to test every possibility as it arose. And if the suggestion proved to be fruitful it was quite clear that all the results of previous experiments in which larvæ had been blinded admitted of an opposite interpretation to that which they appeared to convey, and one which would carry with it the conclusion that the ocelli really represent the terminal organ for which I was seeking. The experiment is given below:—

Dates.	(*α*) 8 blinded larvæ.	(*β*) 8 unblinded larvæ.
Aug. 28, 10.35 P.M.	Larvæ placed in dark cylinder.	Larvæ placed in exactly similar dark cylinder.
„ 29, 9.45 P.M.	Nearly all suspended, or in Stage III. without suspension.	All suspended, or very near it, except 3 still feeding.
„ 30, 2.0 P.M.	3 have pupated some little time.	3 have pupated some little time.
Sept. 3. Results compared with all pupæ examined Aug. 29 and since that day.	1 on roof was (3). 3 „ „ were light (3). 4 „ floor „ (3). – 8 Thus, altogether, 1 was (3). 7 were light (3). – 8	1 on roof was dark (3). 1 „ „ „ light (3). 1 „ floor „ dark (3). 2 „ „ were light (3). 1 „ side was very dark (3). 1 „ „ „ (3). 1 „ „ „ light (3). – 8 Thus, altogether, 3 were dark (3). 1 was (3). 4 were light (3). – 8

Although the pupæ from the blinded larvæ were rather lighter than those from the unblinded larvæ, no one of either division was lighter than a light (3), and it is clear that there is nothing in the results which can explain the brilliant pupæ produced by blinded larvæ in white or gilt surroundings, except by the supposition that the ocelli have nothing to do with the influence. Inasmuch as the unblinded larvæ are rather

darker, it is obvious that the first of the above questions is also answered in the negative. There is every reason for the belief that these results were not influenced by the blinding one way or the other.

Thus 16 pupæ were obtained from this series.

IX.—A company of nearly mature larvæ was found August 28 on a nettle-bed (at some distance from that on which Series VIII. was found) in a field by the canal close to Port Meadow. These were kept in large, clear, glass-roofed cylinders until full-fed, and as soon as they showed signs of leaving their food the following arrangements were made :—

A. The object of this experiment was to make a decisive test of the reciprocal effects of the colours of neighbouring larvæ when much crowded. In the morning of August 31, 16 larvæ (having left their food) were selected, and 12 of them were placed in one of the smallest cylinders (8·0 centimetres high, 6·0 centimetres in internal diameter), resembling those described in Series V., B., having a similar roof, and background of glazed white paper, with about one-third of the circumference left clear, and facing a strong east light, being about one foot from the window. The floor, however, consisted of a sheet of "opal" glass. The other four larvæ were placed one in each of four other cylinders of the same kind, arranged in a precisely similar manner. All these larvæ, being much advanced, suspended themselves almost at once.

September 1, 9.30 A.M.—All the four isolated larvæ and 11 of the crowded ones had pupated, in most cases the change having taken place some hours.

September 1, 11.30 A.M.—The last larva had now pupated.

September 3.—The comparison was made between these pupæ and a very large number of those of other divisions and series, *i.e.*, with all compared August 29 and since that date.

1	of the 4 isolated pupæ was suspended on the clear side of the cylinder, towards light, low down, and only 8 mm. from edge of white background	It was	(4), not much gold.
1	„ 4 isolated pupæ was suspended on the side of the cylinder very high up and just inside the edge of the background . .	„	(5), but not extreme.
1	„ 4 isolated pupæ pupated on the white opal floor, not being fixed to anything	„	(4), rather more gold than the (4) above.
1	„ 4 isolated pupæ was suspended from the paper roof	„	(5), like the above (5).

Of the 12 crowded pupæ, 7 were suspended from the roof and were all very light . . . . . (3), very uniform.

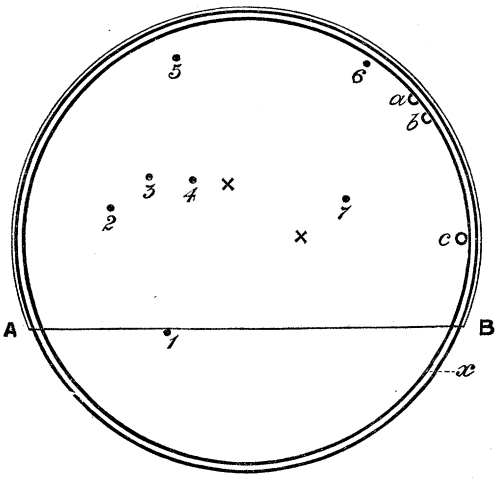
„ „ 3 were suspended from the side against the white background,

of which 1 was suspended from a point 3 mm. below roof;
1 was suspended from a point 2·5 centimetres below roof;
1 was suspended from a point 5·0 centimetres below roof:
} Very light (3), very uniform, and not much gold.

Of the 12 crowded pupæ, two were on the white opal floor and not fixed to anything. They were both (4), typical.

The relative positions of these 12 larvæ are shown in Fig. 2. Natural size.

Fig. 2.



1–7 indicate the positions of the 7 pupæ suspended from the roof.

a. A pupa was attached to the side of cylinder 3 mm. below this point.

b. „ „ „ 2·5 centimetres below this point.

c. „ „ „ 5·0 „ „

× × The two pupæ on the floor were probably suspended from these points in the larval state.

The inner circle represents the actual size of the roof, looked at from below.

x. The space between the two concentric circles represents the thickness of the glass sides of the cylinder.

The sides of the cylinder which bound the area below A—B were clear and uncovered by paper, and turned towards the light.

The fine line outside the cylinder above A—B represents the paper background.

Nothing could well be more conclusive than the above comparison; of the crowded pupæ, 9 out of 12 come within a very short distance of each other, and are all (3); while the remaining three are more isolated in position, and the two most isolated of these are (4). Furthermore, those more completely isolated in separate cylinders are (4) and (5), not one of them reaching (3). The experiment (with others already described) seemed so conclusive that I did not consider it necessary to seek further

proof of the susceptibility of these larvæ to the dark colour of the bodies of their neighbours. This experiment is also a very good test of the influence of white surfaces upon the larvæ, and compares in an interesting way with the other divisions of this series in which gilt surroundings were used.

B. The experiments upon shorn larvæ had shown that the sensitive surface for which I was searching did not exist on the bristles, and the blinding experiments had also led to negative results. Yet the theory that the ocelli do represent the desired terminal organ affected by the coloured surroundings seemed so probable that I was desirous of obtaining other support for the experiments, which seemed at first sight to overthrow the theory so completely. These larvæ are very active, and when blinded or irritated in other ways fling their heads about in the most violent manner, and I feared that the varnish might in this way have been accidentally knocked off one or more of the six ocelli on one or both sides. In the most careful experiments the application of varnish had been repeated, so that three coats had been given in many instances, but the larvæ had been violent whenever the process was repeated. Again, it seemed possible that if the varnish had not been removed it might have been made thin and partially transparent over the ocelli, most of which project considerably. In spite of these arguments I did not see how my repeated and careful application of varnish could have failed in all cases; I did not expect to find the blinded larvæ as dark as those exposed to black surfaces, but I did expect that they would not be equally brilliant with normal larvæ when both were exposed to white or gilt surfaces, that is, if the ocelli represented the desired terminal organs. But the above considerations made it very desirable to test the ocelli in some other way. I had long thought of another experiment, in which the head and the body of a larva were to be exposed respectively to two different colours, producing the most opposite effects, but the difficulty was in the mode of application. In fact, this difficulty seemed insuperable for Stages I. and II. of the preparatory period, but perhaps might be overcome with a little contrivance for Stage III., in which the larva rests suspended. It was, however, first necessary to decide whether the larva is sensitive to colour during this stage. Previous experiments (V., B.; VI., C.; VII., B.) had not thrown much light on the question, but the numbers employed had been insufficient. I therefore determined to devote the majority of the larvæ of this series to the settlement of this question. It seemed that a decisive answer could be best obtained by the transference of larvæ in sufficient numbers at the beginning of Stage III. from a colour to which they had been up to that time exposed into one which tended to produce the most opposite effect. Quite apart from the chief object to be served by the experiment, *i.e.*, the possible introduction of further experiments, the results would be most interesting on their own account in the further light which would be thrown upon the preparatory period. At 2.30 P.M., August 31, it was seen that the larvæ were nearly all mature, and were beginning to collect on the sides and roof

of the large cylinders in which the stock was kept. At this time, therefore, the arrangements for transference were made. Between 2.30 and 3.15 P.M. 17 larvæ were placed in a large cylinder covered with one layer of black tissue-paper, and with a black floor, the whole being covered with two black opaque mats and placed on the floor in shadow (this is II. of the Table below); 12 larvæ were placed in each compartment of the gilt box, arranged as usual (IV. below), and 12 more in another gilt receptacle (also IV. below), of the following construction. I covered a cylinder (1·86 decimetre in internal diameter and 8 centimetres in height) with gilt paper, and covered it with a gilt-paper roof. The cylinder was placed on its side, with its open end facing the light, and therefore a segment of the side formed the roof, while the back was formed by gilt paper (which would have been the roof in the other and usual position of the cylinders used in these experiments). The open front was closed by a plate of clear glass. This gilt cylinder was made use of in many other experiments, and will be always spoken of shortly as the "gilt drum." Another large cylinder was covered with two layers of black tissue-paper, with a black floor, and placed in shadow (I. below), and into this many of the larvæ from the "gilt drum" and box were transferred at the beginning of Stage III. When transferred, the larvæ were in nearly all cases pinned by the boss of silk, to which the posterior claspers adhered. The experiments, together with their results, are given in a tabulated form below:—

	I.—Transferred from gold into black for Stage III.		II.—In black for the whole period.	III.—Transferred from black into gold for Stage III.		IV.—In gold for the whole period.	
Aug. 31. 9.30-10.15 P.M.	9 transferred 2 suspended from gold drum 4 suspended from gold box 3 near suspension from drum	..	8 larvæ feeding 9 others transferred to gold after this date	2 transferred from black into gold drum; both suspended	..	6 larvæ feeding in gold drum 6 others transferred to black at or after this date	14 larvæ feeding in gold box. 10 others transferred to black at or after this date.
Sept. 1. 9.30-10.45 A.M.	1 pupated some hours Rest suspended (1 only transferred for few hours)	7 transferred 6 from gold box } all 1 from gold drum } suspended	No change	At 9.30 A.M. 1 was seen to pupate (Transferred for about 11½ hours)	7 found suspended in black cylinder; 10.45 A.M., are transferred to gold box	1 pupated some hours	1 pupated some time
11.30 A.M.	No further change	No change	,,	The 2nd has just pupated (Transferred for about 14 hours)	No change	No change	No change
12.25 P.M.	2 pupated, 1 having fallen off roof (2 transferred for about 14½ hrs)	,,	,,	..	,,	,,	3 pupated
12.55 P.M.	No change	,,	,,	..	,,	1 pupating	No change
2.15 P.M.	3 pupated (3 transferred for about 16 hours)	1 had pupated (1 only transferred few hours)	,,	..	,,	1 pupated, and fell down from top	2 pupated 1 pupating
3 P.M.	No change	No change	,,	..	,,	No change	1 pupating
11.50 P.M.	2 had pupated some hours, and 1 was dead (2 transferred about 21½ hours; it cannot have been for a less period than 17 hours)	All had pupated some hours (Transferred about 9½ hours)	4 suspended and (about 7.30 P.M.) 1 on roof Others feeding, except one or two preparing for pupation on the floor	..	5 pupated an hour or two (Transferred for about 12 hours)	All have pupated some hours	4 pupated, 1 of them recently.
Sept. 2. 7.45 A.M.	..	..	No change	..	2 last had pupated (Transferred for longer than the above, but it is impossible to make a correct estimate)	,,	All pupated, except 2 suspended.
6 P.M.	..	..	,,	..	..	..	No change

	I.—Transferred from gold into black for Stage III.		II.—In black for the whole period.	III.—Transferred from black into gold for Stage III.		IV.—In gold for the whole period.	
Sept. 2. 7.30 P.M	..	..	5 pupated (about 6.45 P.M.; hence Stage III. about 24 hours duration) 2 suspended 1 feeding	..	..	..	No change
10.5 P.M. Sept. 3.	..	..	No change, ditto	..	..	..	1 pupating
9.50 A.M.	..	..	1 more had pupated 1 died 1 pupated much later	..	..	..	1 pupated many hours
Result of colour-comparisons:—Sept. 3, except for a few which had not darkened sufficiently; these were compared later	1 had died 4 suspended from roof were all (4), 1 with little gold 4 on floor, of which 2 were light (3), 2 were (4), 1 with little gold — 9 —	All remained suspended to roof: 4 were light (?), 3 were (4), 1 with typical gold, 2 with very little gold for (4) — 7 —	7 pupæ 6 on roof, of which 1 is (2) } very little gold, 5 are (3) } 1 on floor, rather deformed, is (4), little gold, but very light in other ways The protraction of Stage III. is very interesting, and agrees with the results of other experiments; a corresponding protraction of the other stages is probably also indicated by the fact that in this column alone the first pupations are so much later than the first pupations of other columns	1 pupa pinned on gold back is light (3) 1 fastened on to roof to the silk boss of a pupa (removed) is (3) No extra gold on either — 2 —	The 7 pupæ were pinned in a horizontal row to the back of the box, 3 in one compartment, 4 in the other Of the 3, the central one was normal (4); the 2 terminal ones were both (4)—very nearly (5) The 4 others were very uniform, being all very light (3), with rather unusual gold The 2 last to pupate were light (3) and (4)—nearly (5)	1 on floor (gold) is a (4) Of 5 on roof (but not crowded), 1 is light (3), 2 are (4), 2 are (5). All with the gold usual in these degrees, except the (5), which have rather less — 6 —	2 close together on roof of one compartment were a (4) and a (5) normal, 1 near them was (4), 3 others, more isolated, were— 2 . . . (4), 1 . . . (5). In other compartment— 2 fell on to brown-paper floor, and were both very light (3) 2 isolated on roof and back were (5) 4 near together (not crowded) were—the 2 middle ones both light (3); the 2 external ones both (5). — 14 —
	Probably more effect would have been produced if the larvæ had been shifted at the very beginning of Stage III., but the above estimates show that this can only have happened in very few cases						

The results of this Table will be most clearly expressed in the following analysis :—

The degrees of colour from (1), darkest and least golden, to (5), lightest and most golden.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
II. In black for the whole period	..	1	..	5	..	1	..	= 7
I. Transferred from gold into black, for Stage III.	..	..	..	..	6	9	..	= 15
III. „ „ black into gold „ „	..	..	..	1	5	3	..	= 9
IV. In gold for the whole period	..	..	..	..	5	7	8	= 20
								51

Such an analysis speaks for itself; it is quite clear that the pupæ as a whole tend strongly towards the lighter forms, but it is equally clear that Numbers I. and III. are intermediate between the two extremes II. and IV. In the considerably lighter results of the former (I.) we probably see the proof that in the shorter stage, II., the influences are really more potent than in III., which is considerably longer. Similarly Stage II. was passed in black surroundings in the case of III., and its results are darker than those of I. In fact, in both I. and III. the colour in which Stage II. was passed predominates in the result, or rather it is more accurate to say that the gilt surroundings produce more effect in Stages I. and II. than in Stage III. alone. It is also probable that the earliest, most sensitive, part of Stage III. had already elapsed in most cases before transference took place. But further experiments will show the inferior susceptibility of Stage III. under the most favourable conditions, and indeed such a result might have been expected, for, although this stage is, as a rule, so much longer than any other, the larval sensory surfaces are probably only in a condition to be influenced in its most early part, for very rapid changes of pupal construction and shape are going on beneath the surface. These would seem to preclude the possibility of an external shell, shortly to be cast off, having any important physiological relation with the organism beneath. But in Stage II. the larva retains its shape, and the whole of its surface is in close relation with the colour into correspondence with which the pupal tints will afterwards deepen. On the other hand, the posterior part of the suspended larva is alone in close proximity with the surface to which it is fixed. But nevertheless the comparison of III. with IV., and I. with II., shows equally clearly that the larva is susceptible, and to a considerable extent, during Stage III., although the susceptibility is probably confined to the first part of it. Future experiments will supply the means for testing the sensitiveness of the different parts of this stage. This experiment showed that an investigation by the use of conflicting colours applied to Stage III. could be undertaken with, at any rate, a fair prospect of success. After all the other experiments it is almost unnecessary to point out how entirely the former theory of pupal as opposed to larval sensitiveness is broken down by the analysis given above.

C. Another small transference experiment was made with the three larvæ found suspended to the food-plant at 2.30 P.M., August 31, when most of the larvæ were re-arranged. These three were then transferred to the gilt box, two being pinned up against the side and one on the roof.

September 1, 9.30 A.M. All had now pupated; the one on the roof last night, and the two on the side some hours.

September 3, morning. Comparison produced these results :—

Of the 3 pupæ, 1 which pupated evening of Aug. 31 (on roof) was (1), very black pigment.
„ 3 „ 2 „ later (on side) . . . . 1 „ (4), less gold than usual.
1 „ (5), normal gold.

When these three suspended larvæ were transferred August 31, one pupa was also found suspended from the food-plant: it was a light (3).

These results harmonise well with the more complete transference experiments in Division B. The dark transferred pupa was only exposed in the larval state for the last few hours of Stage III., and the resulting colour shows that it could not have been influenced at all. It was evidently an exceptionally dark form for this series. The others were exposed for probably the whole of Stage III. and were much affected, one of them being brighter than any of the transferred pupæ in Division B. The latter result must be also partially due to the fact that the larvæ had been previously exposed to surroundings which were far less dark than those made use of in B.

D. Another experiment was made upon six mature larvæ, which were placed, August 31, 2.30 P.M., in a small cylinder resembling those described in Series V., B., covered with two layers of black tissue-paper, but lined with gilt paper. The larvæ had the opportunity of being influenced by the gold, illuminated by daylight, for a few seconds before the cylinder was placed on a black floor, with another double-layered black cylinder over it, in a dark cupboard.

September 2, 7.30 P.M. The cylinder was not touched till this date, but I had estimated that they would have pupated long before this time, and therefore the cylinder was now removed, and it was found that all six had pupated on the roof and had taken their final colour.

September 3, morning. The pupæ were compared with all the others, giving these results :—

Of the 6 pupæ, 3 were light (3).
1 was . . (4), but with little gold.
1 „ . . (5), not much gold for this degree.
—
5

The colour of the 6th pupa was accidentally omitted from the notes.

It is possible that these results were influenced by the few seconds of exposure to the gilt in a bright light, or by the exceedingly small amount of light which may have penetrated. But, on the other hand, the whole series tends strongly towards the

lighter degrees, and the single (5) may have been merely an individual which tended especially strongly in this direction. The results nevertheless suggested a course of experiments which would be likely to give very interesting results, but which I had not time or material to undertake. The suggested experiments were to ascertain the effects produced by some powerfully acting colour (as gold) under different conditions of illumination. On theoretical grounds it is unlikely that the ratio between the two will prove to be direct, but it is to be expected that diminution in illumination will not be attended by a corresponding diminution in effect.

The number of pupæ obtained in Series IX. was 76, and it is therefore probable that the whole of a rather small company was obtained.

X.—A. The remnant of a company was found August 29 near South Hincksey. It was arranged to make use of the few larvæ (eight only) in an experiment to further test the effect of transference during Stage III. into a colour with an influence opposite to that of the colour to which the larva had been previously exposed.

The experiment was conducted as follows. The gilt box and drum and a black cylinder were made use of:—

	Compartment of gilt box.	Gilt drum.	Black cylinder, with black roof and floor.
Aug. 29, 7 P.M. .	8 larvæ put in compartment, having been captured about 5 P.M.		
„ 8.30 P.M.	4 moved into gilt drum .	4 larvæ introduced.	
Aug. 30, morning, early	Food hardly touched, larvæ crawling up sides or motionless on roof	Food hardly touched, larvæ crawling up sides or motionless on roof.	
„ 11.30 A.M.	„	„	
„ 1.20 P.M.	1 suspended	1 suspended.	
„ 1.50 P.M.	„	Another suspended, and at once moved into black surroundings	1 larva only just suspended, moved from gilt drum.
„ afternoon	„	Another suspended and similarly transferred	A second larva introduced.
„ evening .	2 suspended altogether.		
Aug. 31, 9 A.M. .	2 pupated some time, 1 suspended	2 pupated some time, the time of suspension of 1 not noted	2 pupated: not long, as they have not darkened completely yet.
„ 9 P.M. .	The last pupated recently. 1 larva died.		
Results: Sept. 1. Compared with all examined on this day, and 45 examined Aug. 29	The 3 pupæ were all (4), not much gold, but quite light-coloured, 1 rather darker than any of the 7	The 2 pupæ were both (4), not much gold, but quite light	The 2 pupæ were both typical (4), with typical gold; thus the most golden of the 7, but all are equally light, except 1 of those in compartment of gilt box.

These results are very curious and to some extent accidental, as is proved by comparison with the results of similar, but larger, transference experiments. Such a comparison shows that there is obviously no significance in the gilt surroundings producing *more* effect when acting only in the Stages I. and II. of the preparatory period than when acting in these and in Stage III. also. The highly-marked effects seen in the two transferred larvæ are doubtless somewhat abnormally extreme results of the very powerful influence of gilt surroundings working during a time of very high larval susceptibility, *i.e.*, Stage II.

Thus seven pupæ were obtained from this series.

XI.—I was very anxious to obtain some wild pupæ in order to compare their colours with those of the pupæ which had been the subjects of experiment. From what I remembered of observations in former years, I felt assured that the common degree of colour was that represented by (3), but that (2) and (1) were not uncommon, while the highly gilded forms (4) and (5) were almost unknown, except in pupæ which contain Ichneumon larvæ. This exception is, however, obviously abnormal, and it will be alluded to below. On August 31 I found 15 pupæ of *V. urticæ* on a smooth stone wall, with an east aspect, in Oxford. Inasmuch as the pupæ occurred near together, along one continuous extent of wall, and were about the same age, there is little doubt that they were all produced from the larvæ of a single company. Two-thirds of the pupæ were found under the projecting coping. The colour of the stone was grey from the growth of lichens and from the darkening due to soot, &c. Under the coping the colour was especially dark, and was further intensified by the shadow. The pupæ were not sufficiently crowded for their colour to have been mutually affected.

The pupæ were most carefully compared with 45 others examined August 29, and with all examined September 1, and the results were as follows :—

Of the 15 pupæ, 4 were . . (1), with no gold at all.
1 was . . (2), „ „
7 were dark (3) } Only the minutest spot of gold to be seen on careful examination
3 „ . . (3) } in 2 of these: none in the others.
15

The gold of the two pupæ was in the position in which it always occurs if present at all, *i.e.*, round the base of the small lateral tubercles on the first and second abdominal segments. There was a strongly marked deep reddish tint in the three (3), and to a less extent in five out of the seven dark (3) and in one of the (1). This colour was much deeper than the pink tint so often mentioned in the pupæ of my experiments. It was, however, similar to the red mentioned in Series XII., B. and D., although it was much deeper than in the latter. These 15 pupæ were so different

from all the others that it was very hard to classify them according to the same standard, but I am quite sure that there has been no error in the direction of making them appear too dark; if there has been any mistake, it has been in the other direction.

Thus 15 pupæ were obtained in this series.

XII.—A large company of nearly mature larvæ was found August 31 on a nettle-bed near South Hincksey, different from that on which the other series had been found. In a few days the larvæ became mature, almost simultaneously, and the following experiments were made:—

A. The object of this experiment was to ascertain whether a black surface in a powerful light has a different effect from that of complete darkness.

(α) 13 larvæ were placed in a cylinder covered with two layers of black tissue-paper, and a similar roof; a black floor was added, and the whole was placed in shadow. The experiment and its results are given below:—

Sept. 3, 10.15 A.M.–1.48 P.M.	The 13 larvæ were introduced into the cylinder at these hours, and at various times between them.
„ 11.10 P.M. . . .	5 suspended; all the others except 1 are resting on roof.
Sept. 4, 1.15 P.M.	All suspended except 1, and it is in Stage III. on the floor, unfixed.
„ 6.30 P.M.	2 pupated some little time. (If pupation be estimated at 5 P.M. and suspension at 11 P.M., Sept. 3, Stage III. would be 18 hours; but it was probably longer.)
„ 9 P.M.	2 pupated. (If pupation be estimated at 7.45 P.M. and suspension at 11 P.M., Sept. 3, Stage III. would be $20\frac{3}{4}$ hours; but it was probably longer.)
„ 12, MIDNIGHT . .	3 pupated. (If pupation be estimated at 10.30 P.M. and suspension at 11 P.M. for 1 of the larvæ, Stage III. would be $23\frac{1}{2}$ hours; but it was probably longer.)
Sept. 5, 10 A.M.	All have pupated some hours. (If pupation took place at 5 A.M. and suspension at 6 A.M., Sept. 4, Stage III. would be 23 hours; but the estimate is very rough.)
Results of comparison, Sept. 7 (with all others mentioned as compared on this day).	1 pupa on floor was (3), lightish, but not a light (3). 1 „ on side was light (3), with little gold, but more than any other of the 13. Of the 11 pupæ scattered over the roof, but not crowded— 2 were (1), very black indeed. 2 „ (2). 4 „ dark (3). 2 „ (3). 1 was light (3). 13

(β) 14 larvæ were placed in a similar shallow black cylinder, which was then made to rest on its side with the open end covered with a clear glass plate, directed towards a strong east light, and close to the window. Hence the roof of the cylinder was a segment of the side (in the other position), and the ordinary roof of black tissue-paper formed the back. The experiment and its results are given below:—

Sept. 3, 10.15 A.M.–3 P.M. .	The 14 larvæ were introduced into the cylinder at these hours, and at various times between them.
„ 3 P.M.	1 suspended. (About 12.23 P.M.)
„ 3.45 P.M.	1 suspended. (About 3.22 P.M.)
„ 6.15 P.M.	1 suspended (about 5 P.M.), but all the rest on the top.
„ 11 P.M.	2 suspended (about 8.23 P.M.), but many others with the boss of silk spun and ready for suspension.
Sept. 4, 9.25 A.M.	All 14 suspended, but no pupation yet.
„ 1 P.M.	2 pupated an hour or so. (If pupation be fixed at 12 A.M., the duration of Stage III. would be 23 hours 37 minutes and 20 hours 38 minutes respectively.)
„ 6.30 P.M.	7 pupated at various times since the hour last noted. (If 3.45 P.M. be estimated as the time of pupation, Stage III. would be $22\frac{3}{4}$ hours in one case and rather over 19 hours in two others.)
„ 8.30 P.M.	4 pupated; 1 quite recently.
„ 12 MIDNIGHT . . .	1 has now pupated; the last.
Results of comparison, Sept. 7 (with all others mentioned as compared on this day).	All 14 were hanging together from the tissue-paper top of the cylinder, *i.e.*, that part of its side which was uppermost, and which was lined internally with black tissue-paper. There was hardly any gold, or none at all, on these pupæ. Of the 14 pupæ— 3 were rather outlying on one side, and of these 2 were (3). 1 was dark (3). 1 was rather outlying on the other side, and was (3). 10 formed a central group, of which 3 were (2). 2 „ dark (3). 5 „ (3). — 14

Analysing the results of the two experiments, we find the following :—

Degrees of colour: (1), darkest and least golden, (5), lightest and most golden.	(1)	(2)	Dark (3).	(3)	Light (3).	(4)	(5)
(α) Black surroundings in the dark . . .	2	2	4	3	2	..	..
(β) Black surroundings in strong light . .	..	3	3	8	..	..	..

Upon the whole, the results are not widely different, and, as further throwing light on the comparison, I find a note that the light (3) on the side of the cylinder in (α) subdivision is much more golden than any pupæ in the (β) subdivision, which, as a whole, were rather distinguished from the others by the extreme absence of gold. It is to be noted that the larvæ of (β) did not suspend themselves as soon as the others, and therefore passed a longer part of the preparatory period in their cylinders.

The result of the experiment was very satisfactory in its bearing upon the proposed conflicting colour experiments, for in these I could not well place part of a larva in complete darkness, while it would be comparatively easy to surround it by black

surfaces, which this experiment shows to be decidedly efficacious, although not quite equal to the same surface in darkness.

B. The object of this experiment was to test the effect of gilt surroundings on larvæ when they were exposed to its influence for the whole of the preparatory period as compared with exposure during Stage III. only. This was accomplished by placing eight mature larvæ with food in one compartment of the gilt box, and transferring recently suspended larvæ to the same compartment, where they were pinned against the gilt side. Both subdivisions were taken from the stock under clear glass in large cylinders. The experiment was conducted as follows :—

Dates, &c.	(α) 8 larvæ exposed to gilt surroundings for preparatory period.	(β) 3 larvæ exposed to gilt surroundings for Stage III.	
Sept. 3, MORNING	..	2 suspended larvæ pinned in compartment within few minutes of beginning of suspension.	
,, 11.27 A.M.	8 larvæ placed in the compartment	No change.	
,, 3 P.M. . .	1 suspended, 3 resting on roof, 1 wandering, 3 feeding	,,	
,, 6.15 P.M. .	No change	,,	
,, 11 P.M. .	3 suspended, 4 resting on roof . .	,,	
Sept. 4, 8.35 A.M. .	4 ,, 3 ,, ,, . .	2 have pupated 2 or 3 hours. (Hence about 20 hours were passed in the compartment.)	
,, 1 P.M. . .	5 ,, 2 ,, ,,		
,, 1.10 P.M. .	,, ,, ,, . .	..	Another suspended larva added.
,, 1.35 P.M. .	1 has just pupated. (Hence Stage III. is probably very nearly 24 hours long.)	..	No change.
,, 4.15 P.M. .	1 has just pupated. (Hence Stage III. probably about 19–20 hours.)	..	,,
,, 8.50 P.M. .	..	..	It has just pupated.
Results: compared Sept. 7.	1 pupa suspended to side, near the pinned ones, was (4), with normal gold. Of 5 pupæ suspended on roof, 1 was very dark (3). 2 were light (3) with little gold. 2 were (4), 1 with normal gold, and 1 with little. There is no note of pupations later than the above 2. 2 larvæ died.	Both pupæ were light (3), 1 of them very red and black in lower part of abdomen (? diseased). These larvæ must have spent very nearly all Stage III. in the box, and seem to have been somewhat affected.	It is a dark (3). Red in lower part of abdomen. This larva, having been only about $7\frac{1}{2}$ hours in the box, appears to have been unaffected.

The results are analysed in the following Table :—

	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)
6 pupæ exposed to gilt surroundings for the whole period	..	..	1	..	2	3	..
2 pupæ exposed to gilt surroundings for the whole period of Stage III.	..	..	..	..	2	..	..
1 pupa exposed to gilt surroundings for the last part of Stage III.	..	..	1	..	..	..	..

It is probable that the above results indicate, on the whole, the relative susceptibility of Stage III. to the whole period, although, at the same time, the single dark pupa in the first line shows that we must be prepared for exceptions, and that it is necessary to make use of large numbers of larvæ in order to obtain a sufficiently accurate result.

C. It seemed that interesting results might be obtained by exposing a few larvæ during Stage III. to a very powerful direct light, and yet without any coloured background, at a distance which could affect them. If negative results were obtained, they would serve as a confirmation of conclusions rendered probable by other experiments, viz., that the effective influence is due to the presence or absence of reflected light, and its quality, if present, but seldom or never under natural conditions, to direct light falling upon the larvæ. In the following experiments I proposed to place the larvæ under conditions in which they could only be illuminated by direct light. This object was achieved by pinning the suspended larvæ to the central vertical bar of a large east window, the pin being thrust through the boss of silk so far that the larvæ hung suspended from the head of the pin which projected from the side of the bar, so that the whole length of the pin intervened between the larva and the bar (painted stone-colour). Very long pins were made use of in the experiment. The suspended larvæ were taken from the main stock in the cylinders, where they were found fixed to the food-plant. The following Table explains the manner in which the experiment was conducted :—

Sept. 3, 11.30 A.M. .	1 pinned up.	1 pinned up.		
„ 1.5 P.M. . .	„	„	2 pinned up.	
„ 4.45 P.M. .	„	„	1 fell off.	4 pinned up.
„ 6.15 P.M. .	„	„	„	2 pupated; some hours.
Sept. 4, 8.35 A.M. .	„	„	1 dead	1 pupating.
„ 11.0 A.M. .	Pupated some little time.	„	..	
„ 11.30 A.M. .	..	Pupating	..	No change.
„ 1 P.M. . .	..	..	..	1 pupating.
Results:— Compared Sept. 7.	Pupa was (3), normal gold. Thus Stage III. very long, apparently about 22–23 hours.	Pupa was (5), golden, but not extreme for this degree. Thus Stage III. also very long, and at least $22\frac{1}{2}$ hours.		2 first to pupate were dark (3) with rather unusually bright gold for this degree, but the normal amount. 2 next light (3), normal gold. The first two only passed about 8–9 hours in the light. The 3rd $16\frac{3}{4}$ hours, and the 4th $18\frac{3}{4}$ hours.

The results of the experiment are certainly surprising, for I did not expect to find any indications of influence, and at the time of the experiment I did not think that there were any. I was then taking notes and making experiments every hour of the day, and had not time or opportunity to make allowance for the periods during which the larvæ had been under any influence. However, when the notes are worked out in the above tabular form, there seems to be much reason for thinking that some considerable effect was produced. The only two dark (3) among the pupæ were those which were pinned up in the window long after the susceptible part of Stage III. had already passed, and the others, which were exposed for practically the whole of the stage, are certainly lighter than the normal forms. Had I realised these results at the time, I should have made other and much larger experiments, avoiding the source of error introduced by the proximity of the vertical light-coloured bar by suspending the pupæ from fine threads. I hope to make such an experiment in the next season. The results are all the more remarkable because in Division A. it was shown that the powerful direct light had but little influence in opposition to the black surroundings.

D. The rest of the larvæ were almost entirely made use of in the conflicting colour experiments, towards which many other experiments had been leading. Two frames were made on precisely the same principle as a larger one, which will be described and illustrated in the next series, and therefore I need only give a mere outline of the

construction in this place. The bottoms of two flat wooden trays were, in each case, covered with black and gilt paper, the different colours meeting along a line which ran across the tray, and along which a shelf was fixed covered with gilt paper towards the gilt side of the tray, and black towards the black side. The shelves close to the tray bottom were perforated with holes separated by equal distances, and the size of each hole was such as to easily admit the body of a larva, with its spines, but sufficiently small to prevent the occurrence of any considerable space between the edge of the aperture and the larval body. In fact, such space as existed was much obscured by the larval spines. The trays were placed vertically, with the coloured surfaces facing a strong east light, and close to the window, so that the shelves projected horizontally ; but the black surface was uppermost in one tray, and the gilt surface in the other.

Whenever suspended larvæ were found among the food-plant, &c., of the cylinder containing the stock they were pinned on to the part of the trays covered with the upper colour, in such a position over the holes that the head and thoracic segments, and generally the first and second abdominal segments, of each larva passed through a hole into the colour beneath, which tended to produce opposite results. This anterior part of the body being always strongly curved in Stage III., the head with any sensory organs upon it was brought close up to the under-side of the shelf, and thus there was no chance of its being influenced in any way by the colour above the shelf (which was of considerable depth). Thus rather more than half the total skin area was exposed to the upper colour, while rather less than half, together with the head, was exposed to the under colour. If the head contained the sensitive surface which was being sought for, we should expect that the pupa would be coloured according to the influence—already known and gauged—of the lower colour ; but if, on the other hand, the whole larval surface was susceptible to colour we should expect that the results would oscillate sometimes on one side and sometimes on the other, but that, on the whole, the preponderance would be in the direction of the tendencies produced by the upper colour, inasmuch as there was a rather greater surface of skin above the shelf than below it. Beneath the shelf other larvæ were fixed upon the lower colour only in the case of each frame, in order to form a comparison-experiment. In the tabulated account of the experiment, given below, P stands for pupation, and F for placing a larva on the frame ; while r indicates that pupation took place recently, or that the larva was placed on the frame directly after suspension.

Dates, &c.	A. The head and anterior part of larvæ in gilt surroundings; the larger posterior part in black surroundings.											B. The larvæ in gilt surroundings.					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
Sept. 4, 11 A.M. to 12 NOON	11 larvæ put on the frame; all known about suspension is that it had not begun 11.15 P.M., Sept. 3.																
Sept. 4, 3.50 P.M.	..	..	..	..	..	..	..	..	..	..	..	F r	F r				
„ 4.20 P.M.	..	..	..	..	..	P r	..	..	..	..	..	..	..	F r			
„ 6.30 P.M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	F r	F r	F r
„ 8.50 P.M.	..	..	..	..	..	..	..	P r									
	Pupation quite recent in nearly all these cases.																
„ 12 MIDNIGHT	P	P	..	..	P	..	P	..	P	P	P						
Sept. 5, 10 A.M.	..	..	P	P	..	..	..	..	..	..	..	P	P	P	P		
„ 2.30 P.M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	P	P
Results of comparison Sept. 7	(3)	(3)	(3)	Dark (3)	(3)	Light (3)	(3)	(3)	(3)	Very light (3), good deal of gold.	Very dull (3), and with little gold.	(4)	(5)	(4)	(4)	(4)	(4)
	Very dull, with little gold. A slight reddish tinge on posterior part of abdomen in Nos. 2, 5, 7, 8, and 10.											Moderate gold for their respective degrees.					

Dates, &c.	C. The head and anterior part of larvæ in black surroundings; the larger posterior part in gilt surroundings.													D. The larvæ in black surroundings.					
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6
Sept. 4, 11 A.M. to 12 NOON	13 larvæ put on the frame: all known about suspension is that it had not begun 11.15 P.M., Sept. 3.																		
Sept. 4, 1.15 P.M.	..	..	..	..	..	..	..	..	..	..	..	..	..	F					
,, 3.50 P.M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	F r				
,, 5.20 P.M.	..	..	..	..	..	..	..	..	P r	..	..	..	..	..	..	F r			F r
,, 6.30 P.M.	..	..	..	..	..	P r	..	..	..	..	..	..	..	..	..	..	F r	F r	F r
,, 8.50 P.M.	..	..	..	..	..	Pupa fell down injured.	..	P r	..	..	..	..	..						
	Pupation quite recent in nearly all these cases.																		
,, 12 MIDNIGHT	..	P	P	P	..	..	P	..	..	P	P	P	P	P	P	P r			
Sept. 5, 10 A.M. . .	P	..	..	..	P	..	..	..	..	..	..	..	..	..	..	..	P	P	P
,, 2.30 P.M. .	..	..	..	..	..	..	..	..	..	..	..	..	..						
Results of comparison Sept. 7	light (2)	(2)	deformed, but probably (3)	light (3)	light (3)	injured, but probably dark (3)	light (3)	dark (3)	dark (3)	dark (3)	(3)	(3)	dark (3)	very light (3)	(4)	light (3)	light (3)	very light (3)	light (3)
	A reddish tinge on posterior part of abdomen, pronounced Nos. 8, 9, 10, 11, and 13, and slight in Nos. 4 and 5.													Normal gold on all except the (4), which has little for this degree.					

An examination of the dates at which pupation took place in A. and C. unfortunately shows that in nearly all cases an important part of Stage III. had elapsed before the larvæ were pinned on the frames. It is quite clear that A., 6, 8, and C., 6, 8, 9, cannot have been influenced after the transference, and there were probably only two larvæ in A. (3, 4), and two in C. (1, 5), which may be considered to have satisfied the conditions of the experiment. The larvæ which were found to have pupated by 12 P.M., September 4, cannot have passed as much as 13 hours on the frame, and most of them must have had a very much shorter period of time. The larvæ of B. and D., on the other hand, seem to have passed the whole of Stage III. on the frame, and one of the most curious and exceptional things in all the experiments recorded in this paper is the fact that the larvæ of D., surrounded entirely by black for the whole stage, should be lighter than those of A. or D., which were also partially exposed to gilt, and had been on the frame for a much shorter time in nearly all cases. In other respects, however, an analysis of the few results in which the influences had worked for an adequate period of time is very satisfactory.

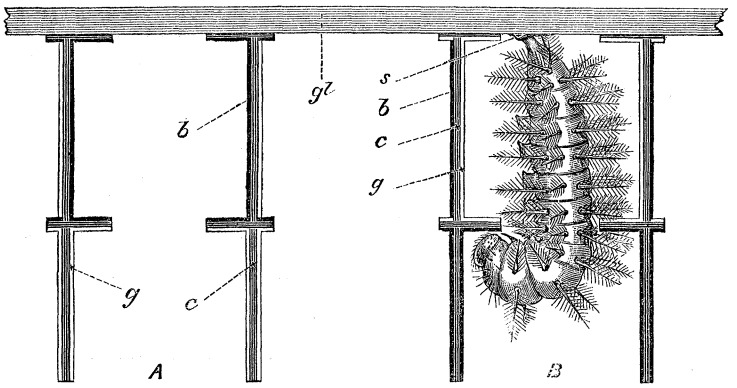
Degrees of colour.	(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)	
A. Larger skin area in black, smaller in gilt for Stage III.	..	..	..	1	1	..	..	..	..	= 2
C. Larger skin area in gilt, smaller in black for Stage III.	..	..	..	..	..	2	..	..	..	= 2
B. Entirely exposed to gilt for Stage III. . . .	.	..	..	..	..	..	..	5	1	= 6
D. Entirely exposed to black for Stage III. . .	..	..	..	..	..	3	2	1	..	= 6
It is interesting to analyse in a similar manner the results of A and C., including those which had pupated at 12 P.M., September 4.										
A.	..	..	..	1	7	..	1	..	..	= 9
C.	..	1	..	2	3	4	..	..	..	=10

The comparison between A. and C. in the upper of the above Tables confirms the results of the previous blinding experiments, showing that no sense-organ in the head can possess the property of being influenced by light in such a manner as to direct the formation of colour in the pupa. Conversely, the results strongly favour the view, and, in fact, confirmed as they are by other experiments, render the conclusion certain, that such a power is possessed by some terminal organ in the skin or by some one of its elements without the intervention of the nervous system. The former is the more probable hypothesis, for, if otherwise, we should expect to find diversely coloured pupæ corresponding to the different colours in the immediate surroundings, but I do not regard this argument as convincing; and the investigation of the structural basis, and the nature of the physiological processes which take place, afford a subject for research which promises results as interesting as the work itself will be difficult. The

upper and more trustworthy analysis, although depending on insufficient data, further supports the conclusion that the influence acts upon the skin by showing preponderating effects from the colour to which the larger area of skin has been exposed; and the differences are small, both between the effects wrought in the pupæ and between the two areas of skin affected by opposite stimuli.

E. Another rather more elaborate plan of conducting the conflicting colour experiments occurred to me, in which each larva was to be kept separate from the others during Stage III. I made a number of short cardboard tubes with two perforated discs in each of them, one disc at one end, and the other near the middle,

Fig. 3. (× 2.)



b. Black. *c*. Cardboard. *g*. Gilt. *gl*. Glass. *s*. Boss of silk. (The black line indicates the black coating, the white margin the gilt coating, while the lines between represent the cardboard substance of the tube.)

dividing the tube into two compartments. The size and shape are shown in fig. 3, which is drawn twice the actual size in all dimensions. In each tube the colour lining one compartment was gold, while black lined the other. The method of application is also shown in fig. 3, *B*, the upper aperture being slipped over the head of the larva, which was then assisted through the lower aperture by the use of forceps; a little glue had been placed on the upper surface of the upper disc, and this was pressed tightly with a slight screwing motion on to the glass, from which the larva was hanging, and in all cases tightly adhered. The larva nearly always remained quiet in the tube, and did not retract its head into the upper compartment. Fearing lest the larva might stretch its head beyond the lower rim of the tube, the external surface, as far as it could be seen from such a point of view, was always of the same colour as the lower compartment, but I do not think that the larvæ ever stretched so far; in fact, the tubes were of such a length that it would have been very difficult for them to do so. All the dimensions were adopted after careful measurement of larvæ in Stage III. The upper compartment was illuminated through the upper aperture, and the lower by the open end of the tube, and also partially through the

space between the larva and the perforation in the lower disc, but this was largely blocked by the larval bristles. The different sizes of the openings through which the compartments were illuminated corresponded to the fact that the light which came down from the window into the upper compartment was far stronger than that which was reflected up into the lower chamber (the glass sheet with the tubes adhering being placed a short distance above an ordinary plain deal table). In order to apply the tubes, the larvæ were induced to suspend themselves from sheets of glass. A number of strips of glass were cut of various lengths, and equal, but narrow, widths (about 4 centimetres), and these were placed together so as to form a number of separate rectangular frames, the angles being secured with gummed paper, a sheet of glass being placed as a roof over the top of each. In this way a number of glass boxes were obtained, having very low sides (4 centimetres), and very large covers. As soon as the larvæ in the stock quitted the food-plant they were turned into these boxes, and, the low sides offering little impediment, they soon mounted to the roof, and prepared for suspension. Some of the boxes were compartmented by another glass strip passing across the centre. In other cases the same results were obtained by placing a sheet of clear glass over a low cylinder of great diameter. In all cases the larvæ of the succeeding subdivisions and those of the next series also were kept in separate glass boxes, compartments, or cylinders. A certain number of larvæ were left free to suspend themselves among the tubes which surrounded the other larvæ, in order to observe the effect of varying proximity to tubes with gilt or black external surfaces as compared with the results produced upon the larvæ inside the tubes. At the same time the results are not very trustworthy, for there is no note as to the time at which the free larvæ suspended themselves, relatively to that at which the tubes were fixed, although in nearly all cases the latter took place at an earlier date.

In the succeeding subdivisions C indicates the time when the suspended larva was covered with a tube, and r that this took place very shortly after suspension began, l being substituted if suspension had begun some hours previously; P indicates pupation, and r that the change had just taken place. In the results, "black below" and "gold below" refer to the lower compartments of the tubes, the upper compartments being always of the opposite colour. Each of the subdivisions below (α, β, &c.) corresponds to a single glass sheet with all the pupæ suspended from it either free or in tubes.

(α) As soon as the tubes had been made on the morning of September 4, a few larvæ, which had not been suspended the night before, were covered (*a*, *b*, &c., in the Table below). At a later date larvæ were covered very soon after the beginning of suspension (1, 2, &c. below) The experiment was conducted as follows :—

Dates, &c.	*a*	*b*	*c*	*d*	*e*	1	2	3	4	5	6
Sept. 4, 11.30 A.M.	Cl	Cl	..	..	..	..	..	..	..	..	..
„ 11.45 A.M.	..	..	Cl	Cl	Cl	..	..	..	..	..	..
„ 1.25 P.M.	..	..	..	..	..	Cr	..	..	..	..	..
„ 2.48 P.M.	..	..	..	..	..	..	Cr	..	..	..	..
„ 4.5 P.M.	..	..	..	..	..	..	..	Cr	..	..	..
„ 4.48 P.M.	..	..	..	..	..	..	..	..	Cr	Cr	..
„ 6.5 P.M.	..	..	..	..	..	..	..	..	..	..	Cr
„ 12 MIDNIGHT	1 Pr (about 12 hours in tube).		1 Pr (about 12 hours in tube).			..	..	..	About 19 hours in Stage III.	About 19 hours in Stage III.	About 18 hours in Stage III.
Sept. 5, 9.35 A.M.	1 P (more than 12 hours in tube).		2 P (more than 12 hours in tube).			P	..	P			
„ 2.30 P.M.	. . . . .		. . . . .			..	..	..	P	P	P
Results, Sept. 7	All known about the beginning of suspension is that it had not begun 11.15 P.M., Sept. 3.					Gold below.	Dead.	Black below.	Gold below.	Gold below.	Black below.
	1 (black below) (3), rather golden; 1 dead.		2 with black below, both light (3); 1 with gold below, light (3). Little gold on all 3, rather more on the last.			(4); gold little for (4).		Very light (3).	(4); gold little for (4).	Very light (3).	(4); gold little for (4).

Four more larvæ were left free to suspend themselves on the glass roof, in a strong east light, among the gilded and black tubes surrounding the larvæ tabulated above.

Results :—

1 pupa suspended near	2 tubes, gilt outside	very light (3) and little gold.
1 „ „	2 „ 1 black and 1 gilt, but nearer the latter	light (3) and little gold.
1 „ „	1 tube, black outside	light (3) „ „ „
1 isolated and fallen down from roof.		very light (3) and little gold.

4

Comparing the dates of covering and pupation of the larvæ, *a*, *b*, &c., it is seen that they were covered for a considerable time, but at any rate a portion (and probably all in two cases) of the important earliest part of the stage must have elapsed before they were applied. There is no evidence for any difference between the colours of the pupæ in these tubes corresponding to the different colours of the upper (or lower) chambers, but the pupæ are not so light as those numbered 1, 2, &c., which were exposed to gold in one compartment or the other for the whole of Stage III. In these latter pupæ the three in tubes with the gold chambers below were, on the whole, *slightly* lighter than the others, but there is hardly any difference. The free larvæ produced pupæ which were intermediate in colour between those numbered *a*, *b*, &c., and those numbered 1, 2, &c., and the individual pupæ show traces of slight colour differences which correspond to their respective environments.

The comparison of these results with all others in which the compartmented tubes were used will be shown by means of a tabulated analysis at the end of the last experiment of the kind in the next series.

(β) The next experiment was conducted as follows, and consists of three sets of larvæ similar to those described in (α) subdivision :—

Dates, &c.	1	2	3	4	5	6	7	8	9	10	11	12	13	6 other larvæ in compartmented tubes.	7 larvæ free in glass box.
Sept. 4, 12.20 P.M. .	Cr	..	..	..	..	..	..	..	..	..	..	..	..	The larvæ were found suspended, and were covered between 12.5 and 12.20 P.M., Sept. 4. All that is known about the beginning of suspension is that it had not begun 11.15 P.M., Sept. 3.	Left free to suspend themselves among the black and gilt tubes surrounding other larvæ.
„ 12.30 P.M.	This larva would withdraw its head into upper compartment	Cr	..	..	..	..	..	..	..	..	..	..	..		
„ 1.30 P.M.		..	Cr	Cr	..	..	..	..	..	..	..	..	..		
„ 2.30 P.M.		..	..	..	Cr	Cr	..	..	..	..	..	..	..		
„ 4.12 P.M. .	At last arranged rightly	..	..	..	..	..	Cr	Cr	Cr	..	..	..	..	12, MIDNIGHT, Sept. 4. 2 had pupated recently, being still green.	
„ 5.13 P.M. .	..	..	..	..	..	..	..	..	..	Cr	..	..	..	9.35 A.M., Sept. 5. All the rest had pupated some time.	
„ 6.12 P.M. .	..	..	..	..	..	..	..	..	..	Stage III. about 19 hrs.	Cr	Cr	..		
„ 9.20 P.M. .	..	..	..	..	..	..	..	..	..		Stage III. about 18 hrs.	Stage III. about 18 hrs.	Cr		
„ 12 MIDNIGHT	..	..	..	..	..	..	..	..	..				Stage III. about 15 hrs.		
Sept. 5, 9.35 A.M. .	P	P	P	P	P	P	P	P	..	..					
„ 2.30 P.M. .	..	..	..	..	..	..	..	..	..	P	P	P	P		
Results, Sept. 7 . .	Black below Very light (3) N.B.—Condition of experiment not rightly carried out; see above	Gold below Light (3) Very little gold	Black below Very light (3)	Gold below Very light (3) Very little gold Pupa fell down	Gold below (4) Little gold Pupa fell down	Black below Very light (3)	Dead	Gold below Very light (3) Very little gold	Dead	Gold below (4) Very little gold for (4)	Black below (4)	Gold below (4) Little gold Pupa fell down	Black below (3)	4 tubes had the gold compartment below, and contained— 2 . . . (4) 1 very light (3) 1 . . . (3) 2 tubes had the black compartment below, containing— 2 . . . (3) and rather darker than the (3) above One of the (4) alone out of the 6 possessed any considerable gold; very little on all the others	1 pupa close to tube gilt outside, and much further from 2 black ones, was (4). 3 pupæ in a square space, with 3 gilt tubes and 1 black one at its corners, were— 1 . . . (4) 2 very light (3) 1 pupa, near 2 black tubes and further off 2 gold tubes, was light (3) 1 pupa, close to 2 gold tubes, was very light (3) 1 isolated, but nearer gold tubes than anything else, was (3), the darkest of all these free pupæ. 7 None of the (4) possessed the normal amount of gold.

N.B.—There is no note as to presence or absence of special gold in the degrees of colour found in pupæ in the tubes with black compartments below; but if this gold had been at all prominent—even normal—it would certainly have been noted.

The results of the above Table are very similar to (α). In the larvæ numbered 1, 2, &c. (omitting 1, because the experiment failed in this case), the pupæ in the tubes with gilt chambers below are a little lighter than those with the black ones below; while greater differences in the same direction are shown in the less trustworthy results obtained from the six larvæ which were covered by the tubes for part of Stage III.; and, as in (α), the latter are on the whole darker than those which had been exposed to gilt surfaces for the whole stage, while the free pupæ are about intermediate, and also seem to show some faint correspondence with the colour of the surrounding tubes.

(γ) Another small subdivision is tabulated below, and only consisted of two larvæ placed in tubes during the whole of Stage III., and of six free larvæ:—

Dates, &c.	1	2	6 larvæ free in glass cylinder.
Sept. 4, 12.25 P.M. .	Cr	..	These were free to suspend themselves among the black and gilt tubes.
„ 4 P.M. . .	..	Cr	
„ 5, 9.35 A.M. . .	P	P	
Results: Sept. 7 . .	Black below	Gold below	2 pupæ on side of cylinder and close together, and both (3).
	Dark (3)	(4) Very pink, but hardly any gold	1 on roof close to tube, black outside, (3).
			1 on roof, about equidistant from gilt and black tube, (3).
			1 on roof near to black tube, dark (3).
			1 on roof, far off a black tube, light (3).
			6

As far as the evidence goes, the tube with the gilt chamber below produced much the greater effect, but the comparison only depends upon two individuals. The free pupæ cannot well be compared with those above, but they are distinctly darker than those in tubes in subdivisions (α) and (β). The pupæ are very uniform, and on the whole do not afford any clear evidence of colour correspondence with the tubes, but at least half of them cannot have been near enough to be influenced at all.

(δ) This subdivision only consisted of the same two sets as those described in (γ). The experiment is tabulated below :—

Dates, &c.	1	2	3	4	5	9 larvæ free in glass box.
Sept. 4, 4.15 P.M. .	Cr	Cr				These larvæ were free to suspend themselves among the black and gilt tubes surrounding the other larvæ.
„ 6 P.M. . .	Stage III., about 17½ hrs.	Stage III., about 17½ hrs.	Cr	..	..	
„ 9.15 P.M. .			..	Cr	Cr	
Sept. 5, 9.50 A.M. .	Pr	Pr	..	Stage III., about 16 hrs.	Stage III., about 16 hrs.	
„ 1.30 P.M. .	..	..	P	Pr	Pr	
Results: Sept. 7 .	Gold below Injured, but appears to be light (3)	Black below Light (3)	Black below Light (3) pupa fell down	Black below Light (3)	Gold below Injured, but appears to be rather darker than light (3)	1 pupa, isolated, was (3). 2 little nearer a tube gilt outside than a black one were both dark (3). 2 equidistant from a black and a gilt tube were both (2). 1 nearer black than gilt tube was (3). 1 some distance from a black tube was dark (3). 1 little nearer gilt than black tube was (3). 1 much nearer black than gilt, quite close to the black, was light (3). – 9

The results of the experiments with the tubes seem to be completely uniform, while the free pupæ are on the whole decidedly darker; and, as in (γ), the individuals do not exhibit any evidence of correspondence with the colours of surrounding tubes.

This subdivision concludes the experiments with compartmented tubes in this series; they will be analysed at the close of the description of similar experiments in the next series.

F. A few pupæ were found among the food, &c., of the cylinders containing the stock of larvæ, and these are interesting as affording a further criterion of the colours assumed, when there is little stimulus from surrounding surfaces, towards either the light or dark forms.

In one of the cylinders containing the stock four pupæ were found, of which two were lying on the plain deal floor (one light (3), one very light (3)), while two were suspended from the side (one dark (3), one light (3)).

In the other cylinder also four pupæ were found, of which two were suspended from the food-plant (both (3)) and two were lying on the floor of white paper, but darkened with food-plant and fæces (one dark (3), one very light (3)). One larva was placed in a tube consisting only of the upper gilt compartment, and thus the only black surfaces below were the lower face of the lower disc and the outside of the cylinder. It was not known how much of Stage III. was passed in the tube. The pupa was (3).

Thus 146 pupæ were obtained from this series. Some of the results of the above-recorded experiments are deferred until after the description of similar experiments in the next series.

XIII.—Another large company of larvæ was found, also August 31, on the large nettle-bed near South Hincksey, upon which three of the previous series were also found. These were kept in clear glass cylinders, and were made use of in the following experiments :—

A. Some of the larvæ which were found suspended in the cylinders containing the stock were transferred to gilt and black surfaces for the rest of Stage III.

Thus, on September 4, 12 suspended larvæ were taken from the clear glass cylinders, where they were attached to the food-plant and clear glass roof, &c., and were pinned against a gilt surface facing a strong east light, close to the glass of the window (about 5 centimetres distant). The larvæ were taken as soon after the beginning of suspension as possible, but there were considerable differences in this respect, as the Table indicates. Similarly eight larvæ were pinned against a black surface under conditions which were otherwise exactly similar. The experiment was conducted as follows :—

Dates, &c.	(α) 12 larvæ transferred from stock to gilt.			(β) 8 larvæ transferred from stock to black.
Sept. 4, 3 P.M. . . .	. . .	. . .	. . . . .	8 suspended larvæ pinned on black surface.
„ 3.15 P.M. . .	. . .	. . .	12 suspended larvæ pinned on gilt surface	No change.
„ 9 P.M. . . .	. . .	. . .	No change	„ „
„ 9.15 P.M. . .	1 just pupated 6 hrs. on gilt	. . .	No change in others . .	„ „
„ 12 MIDNIGHT .	. . .	1 just pupated 9 hrs. on gilt	„ „ . .	1 pupated (less than 9 hrs. on surface) and 1 pupating (9 hrs. on surface).
Sept. 5, 9.55 A.M. . .	. . .	. . .	All pupated some hours .	All pupated some hours.
Results of comparison, Sept. 7	(3) . .	Light (3)	Of the 10 pupæ— 2 were (2) 3 „ (3) 3 „ light (3) 1 was very light (3), unusual gold. 1 was very light (4) with normal gold, but rather dark in other respects, reddish posteriorly. — 10	Of the 8 pupæ— 1 was dark (3) 2 were (3) 5 were light (3) — 8 With the normal moderate amount of gold on half the pupæ.

It is quite certain that the larvæ of which the time of pupation is known only passed the latter half, or even less of Stage III., on the gilt or black surfaces, and it is equally certain that few of the others had been transferred for the whole stage; for, if we assumed that pupation took place in the majority of cases at 5 A.M., September 5, this would only leave 14 hours for Stage III.

It is probably on this account that the colours show so little correspondence with the surfaces on which pupation took place, for there are even two (2) on the gilt surface, although these are compensated by the one (4) and the one very light (3).

B. In the next experiment the compartmented tubes were made use of which were described in Division E. of the last series. These experiments are also divided into subdivisions, each of which corresponds to a sheet of glass with all its suspended pupæ covered and free, and therefore subjected to uniform conditions of illumination.

(α) In the first experiment the larvæ were covered with the tubes for nearly the whole of Stage III., and there were no free larvæ among the tubes. The experiment is shown below :—

	1	2	3	4	5
Sept. 4, 4.40 P.M. .	All covered with tubes soon, but not immediately, after suspension.				
Sept. 5, 9.50 A.M. .	P	P Mostly fallen down		P	
Results, Sept. 7 . .	Gold below (4)	Gold below Very light (3)	Black below Very dark (3)	Gold below (4) Rather dull, but fair amount of gold	Dead

Hence the tubes with the gilt chamber below produced much lighter results than those with the gilt chamber above; and it appears to be probable that the larvæ were decidedly influenced towards the light side of normal, and therefore that but little of Stage III. had elapsed before the tubes were applied.

(β) The next experiment included larvæ in tubes for all Stage III., others for part of the stage, and others free among the tubes.

Dates, &c.	1	2	3	4	5	4 other larvæ in compartmented tubes.	5 larvæ free in glass box.
Sept. 4, 6.30–6.45 P.M.	Cr					Few notes taken, because it was not known how long the larvæ had been suspended when covered Sept. 4, 11.45 P.M., 2 pupated recently Sept. 5, 9.50 A.M., all pupated	These were free to suspend themselves among the gilt and black tubes surrounding the other larvæ. Sept. 5, 9.50 A.M., all pupated.
,, 9.10 P.M. . .	..	Cr	Cr				
,, 11.45 P.M. .	..	..	..	Cr	Cr		
Sept. 5, 12.40 P.M. .	..	..	Stage III., 19 hrs. 20 mins.	Stage III., more than $16\frac{3}{4}$ hours	Stage III., $16\frac{3}{4}$ hours		
,, 2 P.M. . . .	..	..					
,, 4.30 P.M. . .	..	..	Pr		Pr		
,, 10.55 P.M. .	P	..	..	P			
Results, Sept. 7 . .	Dead	Dead	Gold below Very light (3)	Gold below Very light (3)	Black below Very light (3)	2 gold below contained: 1 (4), very light pink and little gold 1 very light (3) 2 black below contained: 1 (2) 1 only partially changed, but apparently a dark (3)	1 close to 1 tube, gilt outside, was dark (3). 1 good deal further off was (2). 3 quite close to 1 tube, black outside, were: 1 dark (3) 1 . . (3) 1 light (3). These all on glass roof. — 5

The results produced after the larvæ had been covered for the whole of Stage III. (*i.e.* 1, 2, &c.) are all the same, the position of the gilt chamber making no difference, while in those covered for a shorter time the difference is very great, the two pupæ in the tubes with the gilt chamber above being very dark, and supplying the only instance of a (2) in the whole of the experiments with compartmented tubes. It is probable, in fact nearly certain, that the darkness of these two pupæ is at any rate partially due to individual tendencies or to influences which acted before the larvæ were covered. There are no evidences of any colour-relation between the free pupæ and the neighbouring tubes.

(γ) In this, the last experiment with compartmented tubes, I removed the upper

perforated disc from each tube, believing that I had in the other experiments allowed far too much for the greater illumination of the upper chamber. The results of the experiment are shown below :—

Dates, &c.	1	2	3	4	5	7 larvæ free in glass box.
Sept. 5, 12.5 P.M. . . „ 2.15 P.M. . . „ 4.30 P.M. . . „ 11 P.M.	Cr	Cr ..	Cr	Cr	Cr	These were free to suspend themselves among the gilt and black tubes surrounding the other larvæ. Time of pupation unknown.
Results, Sept. 7.	Gold below (4) Very light and pink, but little gold	Time of Black below (5) Rather dull for this stage	pupation Dead	unknown Dead	Dead	4 on glass roof of cylinder :— 2 isolated, both (4), very light and pink, but little gold. 1 close to a tube, gilt outside, (4) as above. 1 close to 2 tubes, black outside, very light (3); resembling the others, only dotted over with dark pigment. 1 on side, isolated, (4) as above. 2 on floor; both (4) as above. 7

Most unfortunately only two larvæ underwent the final change, and at this time the stock of larvæ was exhausted, and no more could be obtained until another season. Had I been able to find them, I much wished to make a large number of experiments with tubes in which the upper disc was removed. However, as far as the experiment goes, it strongly supports my impression that the predominance of colour-effect produced by tubes with the gilt chamber below is entirely due to the much greater illumination from the wider lower opening. This will be alluded to below in discussing the analysis of all results obtained after the use of compartmented tubes. In this experiment the pupa in the tube with the gilt chamber above was a somewhat dull (5), but nevertheless the only (5) obtained in any of the experiments with the tubes. Among the free larvæ there is some colour-correspondence with the neighbouring tubes, which certainly suggests some influence on the part of the latter. It is interesting to note the extremely light results of experiment (γ) as a whole.

Before concluding the experiments of Series XIII., it is best—now that all the results obtained by the use of tubes have been described—to analyse the colours obtained in all subdivisions in which this method has been employed in this and the preceding series. The analysis is given below :—

SERIES XII., E.—α, β, γ, δ.

	Degrees of colour.	(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)	Totals.	
α.	Larvæ in tubes, Stage III. Gold chamber below, rather more skin in black	..	..	..	..	..	..	1	2	..	= 3	Almost equal, but some preponderating effect follows when the gold chambers are below.
	Larvæ in tubes, Stage III. Black „ „ „ gold.	..	..	..	..	..	..	1	1	..	= 2	
	Larvæ in tubes, part of Stage III. Gold „ „ „ black	..	..	..	..	..	1	..	..	..	= 1	Results equal as far as evidence goes; darker than the above.
	Larvæ in tubes, part of Stage III. Black „ „ „ gold.	..	..	..	..	1	2	..	..	..	= 3	
	Larvæ free among tubes	..	..	..	..	..	2	2	..	..	= 4	Results intermediate between the two sets compared above.
β.	Larvæ in tubes, Stage III. Gold chamber below, rather more skin in black	..	..	..	..		1	2	3	..	= 6	Rather preponderating effects when the gold chamber below.
	Larvæ in tubes, Stage III. Black „ „ „ gold.	..	..	..	..	1	..	2	1	..	= 4	
	Larvæ in tubes, part of Stage III. Gold „ „ „ black	..	..	..	..	1	..	1	2	..	= 4	Decidedly preponderating effects when the gold chamber below; a little darker than the above.
	Larvæ in tubes, part of Stage III. Black „ „ „ gold.	..	..	..	..	2	..	..	..	..	= 2	
	Larvæ free in glass box, &c., among tubes	..	..	..	..	1	1	3	2	..	= 7	Intermediate between the above sets.
γ.	Larvæ in tubes, Stage III. Gold chamber below, rather more skin in black	..	..	..	..	..	..	..	1	..	= 1	Results very different; great preponderance when the gilt chamber is below.
	Larvæ in tubes, Stage III. Black „ „ „ gold.	..	..	..	1	..	..	..	..	..	= 1	
	Larvæ free among tubes	..	..	..	1	4	1	..	..	..	= 6	Probably normal for free pupæ, and the same as the second set.
δ.	Larvæ in tubes, Stage III. Gold chamber below, rather more skin in black	..	..	..	..	..	2	..	..	..	= 2	Results equal.
	Larvæ in tubes, Stage III. Black „ „ „ gold.	..	..	..	..	..	3	..	..	..	= 3	
	Larvæ free among tubes	..	2	..	3	3	1	..	..	..	= 9	Probably normal for free pupæ, and darker than the above sets.
											58	
Totals	Larvæ in tubes, Stage III. Gold chamber below, rather more skin in black	..	..	..	..	..	3	3	6	..	=12	Decidedly lighter than in the set next below.
	Larvæ in tubes, Stage III. Black „ „ „ gold.	..	..	..	1	1	3	3	2	..	=10	Lighter than normal.
	Larvæ in tubes, part of Stage III. Gold „ „ „ black	..	..	..	..	1	1	1	2		= 5	Decidedly lighter than in the set next below; not so light as first set.
	Larvæ in tubes, part of Stage III. Black „ „ „ gold.	..	..	..	..	3	2	..	..	..	= 5	About normal.
	Larvæ free among tubes	..	2	..	4	8	5	5	2	..	=26	Normal, about; darker than all the above sets except the last.
											58	

Series XIII., B.—α, β, γ.

	Degrees of colour.	(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)	Totals.	
α.	Larvæ in tubes, nearly all Stage III. — Gold chamber below, rather more skin in black	..	..	..	..	..	..	1	2	..	= 3	Results very different, and the dark pupa in tube with gilt chamber above may be abnormally dark; the others normal.
	Black „ „ „ gold.	..	..	1	..	..	..	..	..	..	= 1	
β.	Larvæ in tubes, Stage III. — Gold „ „ „ black	..	..	..	..	..	..	2	..	..	= 2	Results equal.
	Black „ „ „ gold.	..	..	..	..	..	..	1	..	..	= 1	
	Larvæ in tubes, part of Stage III. — Gold „ „ „ black	..	..	..	..	..	..	1	1	..	= 2	Results much stronger when gilt chamber below, but the others are probably abnormally dark for those in tubes.
	Black „ „ „ gold.	..	1	..	1	..	..	..	..	..	= 2	
	Larvæ free in glass box, &c., among tubes	..	1	..	2	1	1	..	..	..	= 5	Probably normal for free pupæ, and darker than the above sets, except for the two last pupæ.
γ.	Larvæ in new kind of tube, Stage III. — Gold chamber below, rather more skin in black	..	..	..	..	..	..	..	1	..	= 1	Stronger results when the gilt chamber was above.
	Black „ „ „ gold.	..	..	..	..	..	..	..	..	1	= 1	
	Larvæ free among tubes	..	..	..	..	..	..	1	6	..	= 7	Very light pupæ, much the same as the upper of the two sets.
											— 25	
Totals	Larvæ in tubes, Stage III. — Gold chamber below, rather more skin in black	..	..	..	..	..	..	3	3	..	= 6	Lighter than the set next below.
	Black „ „ „ gold.	..	..	1	..	..	..	1	..	1	= 3	Much lighter than normal.
	Larvæ in tubes, part of Stage III. — Gold „ „ „ black	..	..	..	..	..	..	1	1	..	= 2	Much lighter than the set next below; same as first set.
	Black „ „ „ gold.	..	1	..	1	..	..	..	..	..	= 2	Darker than normal.
	Larvæ free among tubes	..	1	..	2	1	1	1	6	..	=12	Normal except in the number of (4), and darker than all the above sets except the last.
											— 25	
Complete total of all pupæ in compartmented tubes and of those free among them.	Larvæ in tubes, Stage III. — Gold chamber below, rather more skin in black	..	..	..	..	..	3	6	9	..	=18	Decidedly lighter than below; the lightest of all.
	Black „ „ „ gold.	..	..	1	1	1	3	4	2	1	=13	Much lighter than normal.
	Larvæ in tubes part of Stage III. — Gold „ „ „ black	..	..	..	..	1	1	2	3	..	= 7	Much lighter than the set below, about the same as the one immediately above.
	Black „ „ „ gold.	..	1	..	1	3	2	..	..	..	= 7	Darker than normal.
	Larvæ free among tubes	..	3	..	6	9	6	6	8	..	=38	Normal except perhaps in the number of (4); darker than all the above sets, except the last.
											— 83	

In the above Table it is seen that the difference in the position of the gilt chamber corresponds with a larger difference in pupal colour when the larvæ were covered for part of Stage III. than when they were covered for the whole of it. And the difference is made by the increased darkness of the pupæ of the former set in tubes with the gilt chamber above (especially in XIII.), while the pupæ in the other tubes of the same set are as nearly as possible identical with those in similar tubes, but which had been covered for the whole stage. This is probably due to the fact that the gilt chamber when below was strongly illuminated, and could produce effects even when working for something short of the whole stage—although it is very likely that large numbers of experiments would show that such effects are not so great as when the influence worked for the whole stage, while the less illuminated upper chamber failed to have any effect except when working for the whole stage.

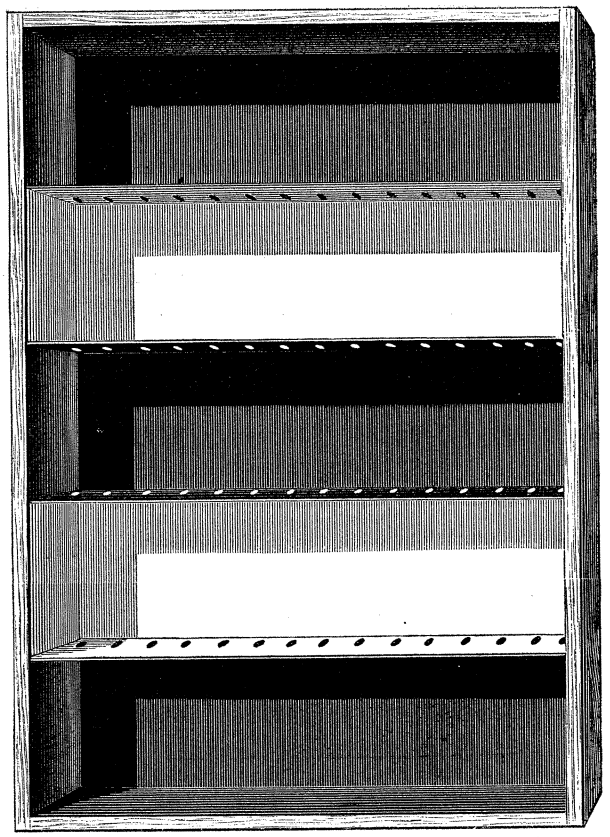
If the results obtained were merely those of the last three lines of the complete total, it would make the conclusion as certain as the conditions of this experiment and the numbers employed could make it—that the influence *does* make itself felt through some anteriorly placed sense-organ situated in the lower chamber, and affected by its colour alone. Accepting the free larvæ as on the whole normal, it is seen that when the head was in black surroundings the pupæ are in no instances as light as the two lightest degrees attained among the normal ones; but when, on the other hand, the head was in gilt surroundings the pupæ never reach the two darkest degrees of the normal pupæ. But such conclusions are quite upset by the further comparison with the far more trustworthy results of the pupæ which were covered for the whole of Stage III. Here also the pupæ in tubes with the gilt chamber below are rather lighter, but the others, although not equally light, are lighter than the free pupæ. It has been suggested above that the free pupæ are about normal, and I think that this suggestion is confirmed by a comparison with the pupæ found on the food-plant and in the cylinders in which the stock was kept (see below, D.) The influence of a colour—black or gold—felt by a larva must be immensely different according as the latter is inside a tube or outside it, and it may well be that the effects in the last case are so slight as to be often inappreciable when the stimulus has been applied during Stage III. only. Certainly in the above-described experiments the facts of one set of free pupæ seeming to indicate a slight influence are compensated by those of the next, in which the results are highly irregular. I believe, however, that the effects were real in a few instances, although very slight, but there is insufficient evidence for the belief in these experiments alone.

Assuming, then, that the free pupæ are not far from normal, we see that the pupæ in tubes for the whole of Stage III. are lighter, whatever be the position of the gilt chamber; the gold has a more powerful influence than the black with either system of relative position. But such results are quite inconsistent with the theory that the larval ocelli are influenced by the colour, for it is seen that the gold produces effects when it is shut off from the anterior part of the body together with the head. The

alternative hypothesis—that something in the skin is sensitive to colour influences—seems at first sight to be opposed by the stronger effects which followed the application of the stimulus to the smaller, anterior, skin area. But, in the first place, the difference between the sizes of the two areas was very small, for the anterior part is much swollen before pupation; and, furthermore, I now feel sure that I over-compensated for the greater illumination of the upper chamber. I did not allow for the fact that the larva always spins a film of silk over the glass for a considerable distance round the boss from which it is suspended, and that the transparency is much impaired in this way. Finally, it has been shown that when in the last experiment (XIII., B., γ) there was an equally large opening to the upper as to the lower chamber the gilt surface when above did actually produce greater results than when it was below, although the conclusion is only supported by a pair of pupæ (the sole survivors in this experiment). Although there are so few, the fact that the only (5) out of 83 pupæ was thus produced is certainly important testimony. Finally, when we compare these results with those of the more perfect conflicting colour experiments conducted with the frames previously described (XII., D.), and which will be further mentioned below, we see that the above explanation of the effects produced in the compartmented tubes is probably correct; that such results show that the sensitive surface is not represented by a sense-organ in the head, or with an anterior position only; while, on the other hand, when all the conditions of experiment are considered, the results harmonise well with the converse theory of a general susceptibility of the larval skin to the influence of certain colours.

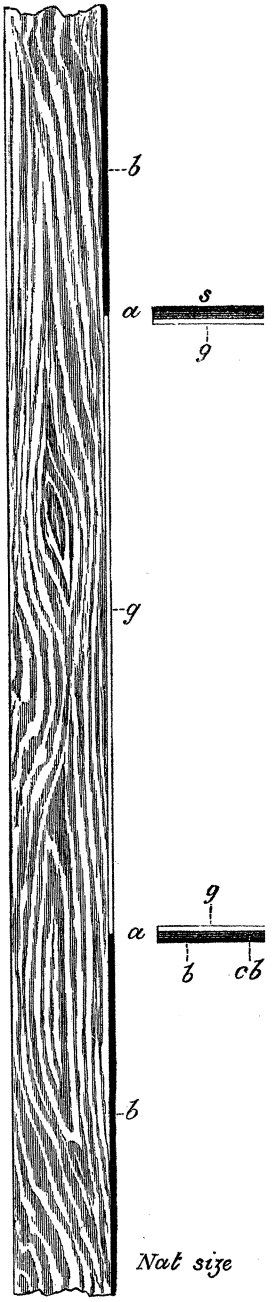
C. Notwithstanding the order in which the above experiments are arranged, the use of compartmented tubes was an earlier contrivance than the frames mentioned in XII., D., and by the end of the last experiments I realised that the latter method was far better, because of the equality of illumination, whether the gilt area was above or below. I therefore made a larger and better frame, of which a drawing is shown in fig. 4 ($\frac{1}{4}$ the real size), while a section is shown in fig. 5 (of the actual size). Upon the frame were pinned all the larvæ which were found suspended in the stock cylinders, for those covered by the tubes were previously placed during Stages I. and II. in special boxes or cylinders. Unfortunately, the larvæ on the frames began to pupate almost at once, and out of the 56 larvæ only seven can have been subjected to the colours for nearly the whole of Stage III., while eight others had been on the frame for about 12 hours (two-thirds of the stage). The experiment is shown below in a tabular form :—

Fig. 4.



¼ real size.

Fig. 5.



Larvæ.	A. Head and smaller anterior part of larvæ in gilt surroundings; larger posterior part in black.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sept. 5, 10.10 A.M. to 11.50 A.M.	..	..	..	..	..	P	..	..	..	..	..	..	..	..
„ 11.50 A.M. to 2 P.M. .	..	P	..	P	..	..	..	..	..	..	..	..	..	..
„ 4.45 P.M.	P	..	..	..	..	..	P	..	P	..	..	..	P	..
„ 11 P.M.	..	..	P	..	P	..	..	P	..	..	P	Pr	..	Pr
Sept. 6, MORNING	..	..	..	..	..	..	..	..	..	P	..	..	..	..
Comparison, Sept. 7	Injured, light (3)	Very light (3), good deal of gold.	(3)	Light (3)	Dark (3)	Light (3)	(2)	(2)	(3) Rather more gold than usual	Very dark (3)	Dark (3)	Light (3)	(2)	Dark (3)

Larvæ.	B. Larvæ in gilt surroundings.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sept. 5, 10.10 A.M. to 11.50 A.M.	P	..	..	P	..	P	..	..	..	..	..	..	..	..
„ 11.50 A.M. to 2 P.M. .	..	..	..	..	..	..	P	..	..	..	..	..	..	..
„ 4.45 P.M.	..	P	P	..	P	..	..	..	..	..	..	..	P	P
„ 11 P.M.	..	..	..	..	..	..	..	P	P	..	P	Pr	..	..
Sept. 6, MORNING	..	..	..	..	..	..	..	..	..	P	..	..	..	..
Comparison, Sept. 7	(4) Normal gold	(2)	(3)	Light (3), unusual gold	Dark (3)	(4) Very brilliant gold, though little of it.	(3)	Dark (3)	Dead, discoloured	Very dark (3)	Very dark (3)	Light (3)	Very dark (3)	(4) Very brilliant gold, though little of it.

Larvæ.	C. Head and smaller anterior part of larvæ in black surroundings; larger posterior part in gilt.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sept. 5, 10.10 A.M. to 11.50 A.M.	..	..	..	..	P	..	P	..	..	..	..	..	..	..
„ 11.50 A.M. to 2 P.M.	P	..	..	..	..	..	..	..	..	..	..	..	..	..
„ 4.45 P.M.	..	P	..	P	..	..	..	..	..	..	..	..	..	P
„ 11 P.M.	..	..	Pr	..	..	Pr	..	P	Pr	..	..	P	..	..
Sept. 6, MORNING	..	..	..	..	..	..	..	..	..	P	P	..	P	..
Comparison, Sept. 7	Very dark (3)	Dark (3)	(2)	Injured, probably (3)	(4) Dull, but with good deal of gold	Light (3)	(2)	(2)	(4) Very light pink, gold also present	(5) Not much gold for this degree	(3)	Very light (3)	Imperfectly pupated; apparently light (3)	(2)

Larvæ.	D. Larvæ in black surroundings.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sept. 5, 10.10 A.M. to 11.50 A.M.	P	..	..	..	..	..	P	..	..	..	..	..	..	..
„ 11.50 A.M. to 2 P.M.	..	P	..	..	..	P	..	..	..	..	..	..	P	..
„ 4.45 P.M.	..	..	P	..	..	..	..	..	..	..	..	P	..	..
„ 11 P.M.	..	..	..	Pr	Pr	..	..	P	..	..	P	..	..	P
Sept. 6, MORNING	..	..	..	..	..	..	..	..	P	P	..	..	..	..
Comparison, Sept. 7	(3)	Injured, light (3)	(2)	Dark (3)	Light (3)	(4) Though with little gold.	(3)	(2)	Light (3)	Light (3); unusual gold, but very dark pigment.	Very dark (3)	Lost	(3)	Lost.

The larvæ were pinned on the frame between 10.10 A.M. and 11.50 A.M., September 5, and several are seen to have pupated almost immediately, and before the process of pinning could be completed.

The pupæ were arranged in four rows, A, B, C, D, and the larvæ were taken from the roof, sides, and food-plant of both cylinders containing the stock of this series. When any group of suspended larvæ was found on any part of the cylinders they were always pinned, one after the other, on all the rows, viz., first A 1, then B 1, C 1, D 1, and then beginning again at A 2, and so on. In this way any tendencies possessed by the individuals of each group (due to time of suspension, reciprocal effects of the black larval surfaces, &c.) were, as far as possible, compensated, and we can trace the effects of this method in the results. Thus No. 8 in each row is remarkable for exceptional darkness (three (2) and one dark (3)), and each of the four larvæ was found to have pupated at the same time of examination (11 P.M., September 5).

The chief results of this Table are analysed below :—

Degrees of colour :— (1) Darkest and least golden. (5) Lightest and most golden.		(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)
Analysis of pupæ which had changed recently at 11 P.M., or after that time, and therefore had been on frame about 12 hrs. or more in all cases	A	..	..	1	1	..	1	..	..	..
	B	..	..	1	..	..	1	..	..	..
	C	..	1	..	..	1	2	..	1	1
	D	..	..	..	1	..	3	..	..	..

The comparison between the larvæ exposed to the influence of conflicting colours —viz., A and C—is in favour of the view that the larval skin supplies the sensitive surface which is affected by light of certain colour. The results produced on the larvæ upon the single colours, black or gold, viz., B and D, are less satisfactory, but the numbers are very small. If the eight larvæ which must have been longest on the frame are analysed alone, we obtain the following results :—

Degrees of colour :— (1) Darkest and least golden. (5) Lightest and most golden.		(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)
Analysis of pupæ which had changed on the morning of Sept. 6, and which had therefore probably in most cases passed nearly the whole of Stage III. on the frame	A	..	..	1	..	..	..	..	..	..
	B	..	..	1	..	..	..	..	..	..
	C	..	..	..	..	1	..	1	..	1
	D	..	..	..	..	..	2	.	..	..

Here, again, the comparison between A and C affords very complete support to the above-mentioned theory as to the larval sense-organs which are affected; but B and D are also unsatisfactory, and it is very likely that one or more out of these three larvæ

in the two rows may have pupated soon after 11 P.M., September 5, and thus may have only spent two-thirds of Stage III. on the frame. I do not urge this because of the confliction of the results with A and C, but because of the earlier transference experiments, in which results were distinctly shown to follow from exposure during the whole of Stage III., and this in spite of the previous influence of colours tending to cause an opposite effect (see results of Series IX., B.). It now remains to add together the most trustworthy results of this experiment as shown in the last Table, and the most trustworthy results of the similar experiment in the last series (XII., D.).

Degrees of colour.	(1)	(2)	Very dark (3)	Dark (3)	(3)	Light (3)	Very light (3)	(4)	(5)	
A. Larger skin area in black, smaller in gilt for Stage III.	..	..	1	1	1	..	..	..	..	= 3
B. Entirely exposed to gilt for Stage III.	..	..	1	..	..	..	..	5	1	= 7
C. Largest skin area in gilt, smaller in black for Stage III.	..	..	..	..	1	2	1	..	1	= 5
D. Entirely exposed to black for Stage III.	..	..	..	..	..	5	2	1	..	= 8
										23

The comparison between A and C, and between either of them and B, entirely supports the above-mentioned conclusion, while such results cannot be made to harmonise with the theory of a sense organ of this kind in the head. The results of D remain as a difficulty under any theory, and I can only account for it by supposing that the individuals were unusually light.

At the close of these long series of conflicting colour experiments, entirely directed towards the settlement of the important question of the position of the sensory surface, I must again point out that all the results which were to be gauged have been acquired from the influences working during Stage III. only, and very often for only part of it, and that all previous experiments of the kind have pointed towards the conclusion that such results must be highly irregular, and can only be brought to bear as evidence by the use of large numbers. I could not, and did not, expect that the results would be more regular than they have proved to be, but I expected sufficiently clear results to confirm or to upset the conclusions arrived at from the numerous blinding experiments, and I think that the results have ended in as complete a confirmation as the necessarily limited conditions of experiment could be anticipated to produce. It will be unnecessary to further summarise any of the conflicting colour-experiments.

D. Finally, towards the close of the experiments, 20 pupæ were found on the food-

plant or floor of the cylinders in which the stock was kept. These are useful as affording criteria of the normal tendencies of this series. By "normal" I mean, in such cases, the tendency which manifests itself when the larva is placed among colours to the influence of which it is not sensitive; and the resulting pupæ deserve the name "normal" for another reason—because they are generally the commonest forms met with. But that they are the commonest merely implies the continual selection of certain surroundings which do produce effects on the larva, so that we see that the continual repetition of an influence of a certain kind, always, generation after generation, producing its corresponding effects, may gradually wear out for itself a line of least resistance along which the formation of pupal colours will always tend to travel, not only when the appropriate stimulus is present, but also in the absence of any colour which can act as a stimulus to the larva. Hence, in Mrs. BARBER'S paper, we learn that by far the commonest forms of the pupa of *Papilio nireus* are deep green, because they nearly always pupate among green leaves, and thus the deep green pupæ, again and again formed, became the "normal" form, or that variety which most individuals will assume in the absence of anything which can be a stimulus. Accordingly, we find in Mrs. BARBER'S experiments that pale green and yellowish and purplish-brown all acted as stimuli and produced pupæ of corresponding colours, but that scarlet could not act as a stimulus (except to the formation of a small part of the colour), and that the resulting pupæ were not scarlet, but were of the commonest deep green colour. It is interesting to note the completeness of the failure of the stimulus in this instance, for the purplish-brown pupæ, if produced, would have been far less conspicuous on the scarlet cloth than the pupæ which were actually produced. And similar facts are to be found in these experiments upon *V. urticæ*, when the larvæ were surrounded by green surfaces, which, in this species, do not act as stimuli.

Therefore it is of great interest to collect careful notes of the pupæ suspended from the food-plant, especially when experiments have been made upon others of the same series. The pupæ of this series were of the following colours :—

Of the 15 pupæ suspended from the food-plant, 5 were . . (4), mostly with normal gold, but rather dull otherwise.
6 „ light (3).
4 „ . . (3).
—
15

Of the 5 pupæ lying on the white paper floor, on which food and dark excreta were also lying . . . . . 1 was . . (4), golden.
1 „ light (3).
1 „ . . (3).
1 „ dark (3).
1 „ . . (2).
—
5

In these results the effects of the white paper floor, although greatly obscured, must not be overlooked as acting upon the pupæ on the food-plant as well as on the floor itself. In this case, of course, the colour exerted its influence during the whole of the preparatory period.

Thus 118 pupæ were obtained from this series, and 598 pupæ altogether from Series III.—XIII., both inclusive, viz., in all the series which correspond respectively to single companies of larvæ. In addition to these, 82 pupæ were obtained from the mixed companies of Series II., and at least 20 in Series I., making a total of 700 pupæ examined, and affording the results upon which the conclusions of this paper are based.

Recapitulation and Conclusions.

It is now necessary to analyse the results of all the experiments in the above series in which larvæ have been exposed to surroundings of different colours during the whole of the preparatory period, or, at any rate, during Stages II. and III., in order to present the entire proof of the influence of certain colours upon the larvæ as contrasted with the powerlessness of others. Incidentally, the negative results of the blinding experiments will be brought out at the same time. The tabular analysis becomes more complex after the earliest experiments because of the further subdivision of the degree of colour represented by (3); but, at the same time, all the shades of difference included under this one degree are together only equal to any one of the other degrees. The colours will be taken in the order in which they were tested. The effects of crowding, &c., cannot be gone into in the following Tables, although they are necessarily excluded in certain cases.

1. Orange :—There was no influence shown in the one experiment in which this colour was used.

2. Green.

Degrees of colour.	(1)	(2)	(3)	(4)	(5)	
Series II. Division C.	..	..	5	1	..	= 6
,, ,, D.	1	3	9	..	..	= 13
,, ,, E.	..	1	3	..	1	= 5
,, ,, F. (blinded) . .	..	4	1	..	1	= 6
,, ,, H.	1	..	5	..	1	= 7
Series III. Division D.	..	..	2	..	..	= 2
Totals	2	8	25	1	3	= 39
Results expressed as percentages of the total	5·1	20·5	64·1	2·6	7·7	

These results show the indifference of the larvæ to the green surroundings very clearly. It is most probable that the slight predominance of the darker forms over the lighter is due to the dim light in the shaded cylinders.

4. Black.

Degrees of colour.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
Not in black all period: Series II. Division G. . .	1	..	..	..	..	..	..	= 1
Not in black all period: „ III. „ C. . .	..	2	..	2	1	1	..	= 6
„ IV. „ A. . .	3	4	4	1	..	..	..	= 12
„ IV. „ B. . .	5	17	13	1	..	..	..	= 36
Groups 1 and 2								
Same conditions: Series VIII. Division A. Subdivision *a*. Blinded	..	..	..	1	7	..	..	= 8
Same conditions: Series VIII. Division A. Subdivision *β*. Normal	..	..	3	1	4	..	..	= 8
Series IX. Division B. Group 2	..	1	..	5	..	1	..	= 7
Same conditions: Series XII. Division A. Subdivision *a*. Black in darkness	2	2	4	3	2	..	..	= 13
Same conditions: Series XII. Division A. Subdivision *β*. Black in light	..	3	3	8	..	..	..	= 14
Totals	11	29	27	22	14	2	..	= 105
Results expressed as percentages of the total	10·5	27·6	25·7	21·0	13·3	1·9	..	

These results show the powerful effects of the black surroundings quite as much in the absence of pupæ in column (5), and the presence of only 2 in (4), as in their abundance in the other columns.

5. WHITE.

Degrees of colour.		(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
Same conditions	Series II. Division J. Subdivision *a*. Unblinded	..	..	..	1	..	..	3	= 4
	Series II. Division J. Subdivision *β*. Blinded	..	2	..	1	..	..	1	= 4
Conditions not quite same	Series III. Division A. Unblinded	..	..	..	5	4	4	2	= 15
	Series III. Division B. Blinded	..	3	..	..	1	2	2	= 8
	Series IV. Division B. Group 3. (But not in white for the whole period)	..	..	5	..	..	..	..	= 5
	Series IV. Division C. . .	..	1	2	8	4	1	..	= 16
Same conditions	Series IV. Division E. Subdivision *a*. Unblinded	..	..	2	1	2	1	..	= 6
	Series IV. Division E. Subdivision *β*. Blinded	..	..	1	3	1	..	..	= 5
	Series V. Division B. Cylinders 2, 3, 6	..	..	..	1	2	..	..	= 3
Same conditions	Series V. Division C. Globes with normal larvæ	..	..	..	3	1	2	..	= 6
	Series V. Division C. Globes with shorn larvæ	..	..	..	2	3	1	..	= 6
Same conditions	Series V. Division D. Subdivision *a*. Shorn.	..	..	1	..	1	1	..	= 3
	Series V. Division D. Subdivision *β*. Normal	..	..	..	..	2	..	..	= 2
Same conditions	Series VI. Division A. Subdivision *a*. Unblinded	..	1	3	3	4	1	..	= 12
	Series VI. Division A. Subdivision *β*. Blinded	..	..	2	5	1	3	1	= 12
Same conditions	Series VI. Division B. Globes with unblinded larvæ	..	..	2	4	4	1	..	= 11
	Series VI. Division B. Globes with blinded larvæ	..	..	3	..	4	4	..	= 11
Same conditions	Series IX. Division A. Isolated larvæ	..	..	..	..	..	2	2	= 4
	Series IX. Division A. Crowded larvæ	..	..	..	..	10	2	..	= 12
Totals		..	7	21	37	44	25	11	145
Results expressed as percentages of the total		0	4·8	14·5	25·5	30·3	17·2	7·6	..

These figures show the strong effects of white surroundings in producing gilded pupæ.

6. GILT.

Degrees of colour.		(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	
Same conditions	Series II. Division I. Subdivision *a*. Unblinded	..	..	..	1	..	1	2	= 4
	Series II. Division I. Subdivision *β*. Blinded	..	..	..	1	..	..	1	= 2
	Series IV. Division D. .	..	1	1	5	2	1	1	= 11
Same conditions in the two subdivisions of each pair	Series V. Division A. Subdivision *a*. Shorn	..	..	..	..	1	2	1	= 4
	Series V. Division A. Subdivision *β*. Normal	..	..	..	..	1	3	..	= 4
	Series VII. Division A. Subdivision *a*. Blinded	..	..	..	..	1	4	1	= 6
	Series VII. Division A. Subdivision *β*. Normal	..	..	..	..	4	1	..	= 5
	Series IX. Division B. Group IV.	..	..	..	..	5	7	8	= 20
	Series X. Division A. . .	..	..	..	..	..	5	..	= 5
	Series XII. Division B. Subdivision *a*	..	..	1	..	2	3	..	= 6
	Totals	..	1	2	7	16	27	14	67
Results expressed as percentages of the total		0	1·5	3·0	10·4	23·9	40·3	20·9	..

These figures show that the gilt surroundings have much more powerful effects than the white surroundings in producing gilded pupæ.

It will now be of interest to place the percentages of these various colours below one another to indicate their differences as strongly as possible.

Degrees of colour.	(1)	(2)	Dark (3)	(3)	Light (3)	(4)	(5)	Numbers of pupæ obtained.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	
2. Green surroundings	5·1	20·5	64·1	64·1	64·1	2·6	7·7	39
3. Black ,,	10·5	27·6	25·7	21·0	13·3	1·9	0	105
4. White ,,	0	4·8	14·5	25·5	30·3	17·2	7·6	145
5. Gilt ,,	0	1·5	3·0	10·4	23·9	40·3	20·9	67
Total . . .	..	..	..	..	..	..	..	356

In the above lists the effects of blinding and snipping off the bristles are also recapitulated. The transference experiments and the conflicting colour experiments have been already systematised as far as it is advantageous to do so; for the details are of paramount importance, being absolutely necessary for the interpretation of the

results of experiments in which the colours were only applied for a small part of the time during which the larva is sensitive.

Experiments upon Vanessa atalanta.

Series 1.—Four larvæ of this species were kindly sent to me by Mr. H. L. SURRAGE, and on September 1 two of them were placed in a small glass cylinder surrounded and roofed with two layers of black tissue-paper, and with a black floor. One larva was a dark variety and probably in the stage before the last, while the other was a light variety and in the last stage. At the same time two other similar larvæ—a dark and a light variety, both in the last stage—were placed in one compartment of the gilt box previously described.

Sept. 2. The light-coloured larva in the dark had pupated some few hours. The other larva died.

Sept. 4, 4.20 P.M. The light larva in the gilt box had just suspended itself to the roof.

Sept. 5, 10.38 A.M. The light-coloured larva was pupating. Therefore Stage III. was almost exactly 18 hours in the case of this larva, both limits being obtained with unusual precision. The dark larva pupated subsequently.

Series 2.—Mr. SURRAGE kindly sent me many other larvæ of this species, and of these four nearly mature dark larvæ were (September 10) placed in a small cylinder with a gilt roof and gilt background, extending round half of the internal circumference of the cylinder, the clear side being turned towards a strong light.

On September 14 all had pupated, one upon the food-plant and three upon the roof. Stage III. was estimated at about 20 hours in one case, while in another it must have been at least 24 hours in duration.

At about the same time a few other nearly mature larvæ were placed in a darkened cylinder with black surroundings, and two pupæ were obtained from this experiment.

Three pupæ were obtained from another set of larvæ in a clear glass cylinder roofed with white muslin.

Results.—Thus altogether 6 pupæ were obtained in gilt surroundings, 3 in black, and 3 in clear glass with a white muslin roof. The 9 pupæ of Series 2 were all compared together on September 30, while the 3 pupæ of Series 1 had been compared much earlier and the imagines had emerged. The results, however, appeared to be very uniform.

The pupæ in the gilt surroundings were all very golden for this species, with the magnificent lateral triangular golden patch on the fourth abdominal segment, and with the four dorsal golden patches and sub-dorsal golden tubercles especially bright upon the metathorax and first abdominal segment. The most golden of the

4 pupæ in Series 2 was figured, and is shown in fig. 13, × 2, Plate 26, but there was not much difference between them.

The pupæ in black surroundings were immensely different, the ground-colour being much darker, and the only golden appearance being on the tips of the sub-dorsal tubercle, spreading a very little on to the sides of the latter, while none reached the general surface of the pupa. In Series 2 one pupa was much darker than the other, and in it most of the tubercles have no golden colour on their apices, which are merely of a lighter colour than the rest of the tubercle. This pupa was figured, and is shown in fig. 12, × 2, Plate 26.

The pupæ in the clear glass cylinder were intermediate between the two above-described varieties, but were nearer to the golden ones.

These results are extremely interesting in their specific peculiarities no less than in their harmony with the effects wrought upon the pupæ of *V. urticæ*. As far as the experiments went there was nothing at all comparable to the amount of golden colour common upon the varieties of *V. urticæ* represented by (4) and (5), although the difference between the two forms, caused by the gilt and black surroundings respectively, was exceedingly marked, and the gilt appearance, though limited in amount, was perhaps more brilliantly metallic than in *V. urticæ*. The length of Stage III. seems to be about the same as in the latter species.

The Biological Value of the Gilded Appearance in Pupæ.

It has been long observed by many entomologists that the excessively gilded pupæ which are sometimes found in nature almost invariably contain the parasitic larvæ of the Ichneumonidæ, although Mr. T. W. Wood has proved that this is not necessarily the case. I need hardly say that my own brilliantly golden pupæ, produced by experiment, were entirely healthy, and I had no instance of the presence of parasites in any of them. Large numbers of them were allowed to develope into Butterflies, and these finally emerged in a perfectly normal manner. However, three pupæ of *Vanessa urticæ*, found wild upon the food-plant during the past season (1886), were more golden than is usual in nature, and all three contained parasites. The contrast between the golden pupæ produced by gilded surroundings and by disease certainly indicates that the former is the normal association, the latter being probably merely incidental. It is probable that the diseased state of the larva in some way prevents the formation of pigment in the pupa, and then the golden appearance is formed which is always normally associated with the absence of pigment. It is quite clear that these interesting results of abnormality offer us no explanation whatever of the normal use of the gilded appearance. The first suggestion was made by Mr. T. W. Wood in the previously quoted paper—that a gilded pupa does not resemble any object which is of interest to the enemies of its class; but, looking more like "a piece of gold or brass than anything else," is likely to be passed unnoticed.

The resemblance to brass or gold can hardly be of value, because the only one of these substances which occurs in nature is not sufficiently abundant to offer a model for imitation which is likely to be of any service to the insect; and the same objection holds good against any metal or metallic sulphide, although, as far colour or lustre is concerned, the resemblance to such a substance as iron pyrites would be admirably adapted for protective purposes.

But it is hardly enough to say that the gilded appearance is unlike anything which is usually of interest to insect-eating animals. It is certainly necessary in addition to point to some substance in the surroundings which is also of no interest, and which the pupæ are protected by resembling. And such a substance is, doubtless, found in the glittering mineral mica, which is often metallic and golden in appearance, and which is very widespread and abundant. The shape of the chrysalis of the Vanessidæ is very angular, and strongly resembles a mineral surface, and the usual appearance of the scattered golden patches on a grey ground is exactly the effect produced by the manner in which the flakes of mica occur scattered among other less brilliant minerals in granite and other rocks. It has been shown in the experiments that the excessively golden appearance is only produced in normal pupæ when the surroundings are correspondingly brilliant, and such a stimulus would of course be provided by an unusual abundance of mica flakes, or of exceptionally large crystals of this mineral. Furthermore it has been shown that the tint of the lustrous pupæ varies with the colour of the surroundings, being generally silvery when white paper was used, and golden when a gilt surface was employed. Hence the various tints of mica, white and silvery or dark and golden, would produce the corresponding protective shades of colour on the pupæ. When the brilliant lustre of mica or other minerals of recently fractured and exposed rock-surfaces is dimmed by the process of weathering and growth of lichens a grey colour is produced which would act as a stimulus for the darker varieties of pupa, while the darkest would be formed in the deep shadow of irregular cavities and furrows. Hence the pupæ of the Vanessidæ have two chief varieties to correspond with the two chief conditions of their mineral surroundings—the brilliant exposed and the grey weathered conditions—while any intermediate result would be formed by any intermixture of the stimuli. In this country we do not see the brilliant metallic pupæ of *V. urticæ*, because in our moist climate the rock-surfaces become grey and weathered almost directly, and because man has offered such facilities for pupation by the erection of walls and houses, which also quickly become grey or are built of some colour (*e.g.*, red brick) which probably does not act as a stimulus. But so perfect is the protection in the natural state that it is extremely rare to find the pupæ of these most abundant insects anywhere except upon walls and houses, which, being plane surfaces, do not conceal the angular forms of the pupæ. But the very shape which renders them conspicuous on these artificial mineral surroundings is eminently protective against almost any natural surface of rock. The susceptibility of the species remains, as

these experiments have shown, and the uniformity of pupal colour seen in England merely follows the uniformity of colour in the surfaces selected for pupation.

It is probable that this protective resemblance to mineral surfaces is very ancient, and it must have been acquired in a dry country, where an exposed rock-surface did not weather for a long time; and it may even date from a period when many of our modern aggressive vegetal types had not arisen, and when the predominant green colour of the vegetal kingdom contributed less to the total appearance of land-surfaces. And the kind of food-plant may have assisted in causing the protective resemblance to surrounding rocks, for the common ancestor of all those Rhopalocera which have gilded pupæ may have fed on low herbaceous plants, which might have withered in the hottest part of the year, and upon which any pupa which protectively resembled the green plant would be necessarily conspicuous. Certainly, our three commonest Vanessidæ pass the pupal stage in the summer, and all feed upon nettle; but it would probably need a far larger amount of knowledge of the life-histories of larvæ than we possess to make such a comparison as would lead us to conclude as to the exact conditions under which this specialised form of coloration originally arose. It is interesting, and confirmatory of the above explanation of the biological value of this appearance, to consider the way in which certain Vanessidæ have adapted themselves to the gradual predominance of green in their surroundings. *Vanessa Io* has a green form which, it has been already shown, is commonly produced when pupation takes place among the leaves of its food-plant, and the amount of gilding upon this variety is not such as would attract attention, for it is not nearly so brilliantly lustrous as that described in *V. urticæ*; and, furthermore, the truly gilded form of the healthy pupa has probably never been obtained, for no one has yet subjected it to gilt surroundings. Hence, when it is said that the green form is more golden than the other variety, it is merely compared with the grey pupa produced by dark mineral surroundings, in which there is hardly any gilding, or none at all. *Vanessa atalanta* has no green form, and when it pupates on the food-plant it commonly attaches itself to the roof of a tent made by the larva, by spinning one or more leaves together. The late Mr. Edward Newman describes a most interesting point in this method of concealment which is often (although I believe not always) adopted. He says ('British Butterflies,' 1871, p. 63): "When full-fed it constructs a somewhat more elaborate retreat; it gnaws through the petiole of a leaf, or eats the main stalk of the nettle within a few inches of the top, not quite separating it; the part thus almost separated falls over and completely withers, and this withered portion is formed into a compact retreat; from the roof of this the caterpillar suspends itself by the anal claspers, and in two days becomes a chrysalis." This is an exceedingly interesting fact: the pupa has no green form, but the larva arranges matters so that the dark pupa shall not be surrounded by living green, but by dark withered leaves, and even when it does not gain this additional colour-relation it is well concealed in the tent which the larva has made. But *V. atalanta* very commonly pupates on mineral surroundings after

having wandered from the food-plant, and under these circumstances it makes no attempt at concealment, but hangs freely suspended against a background with which it harmonises in colour. The contrast between the larval habits when it selects vegetal or mineral surroundings for pupation suggests very strongly that its resemblance to the latter is ancestral, while its somewhat laborious adaptation to the former has been far more recently acquired. *V. urticæ*, however, has no green form like *V. Io*, and has not the protective habit of *V. atalanta*, and I find that in Nature it exhibits the strongest disinclination to pupate on the food-plant. In confinement this is also true if it be provided with a surface up which it can readily climb, but the commonest cages are made of glass, which is ascended with difficulty and after foothold has been ensured by spinning a silken surface over the glass. In spite of this, the vast majority of larvæ do ascend the glass sides, and become suspended from the roof. I must also add that the late Mr. EDWARD NEWMAN states of this larva ('British Butterflies,' p. 53) that it prefers for pupation the underside of a nettle-leaf to other situations which he describes as sometimes selected. I can only say of this statement that it is entirely contrary to my experience. It is possible that Mr. NEWMAN'S opinion may have been partially or entirely derived from watching the larvæ in confinement. Among the 13 series of larvæ of this species, described above, it will be found that many were only the scanty remnants of companies, and in nearly all these cases I had previously seen the larvæ, and knew that the companies were large. I made it a practice to leave the larvæ on their food-plant as long as possible, in order to save the trouble of rearing them, and to ensure healthy pupæ. In this way, by miscalculating the time at which they would become adult by some hours, I often came in time to find only a few larvæ remaining, all the others having wandered away in search of a surface on which to pupate. Being very anxious for all the material I could get, I always searched the nettle-beds most carefully, and if any larvæ had been suspended, or had pupated on the food-plant, they would almost certainly have been detected. But throughout the whole of the season I only found three pupæ in this position, and no suspended larvæ, although it would be easy to calculate the number of larvæ which had pupated; when I searched their food-plant there must have been very many hundreds. And the history of these three pupæ is important.

(1.) Was found August 22, 1886, on the large nettle-bed near South Hincksey, on which portions of two companies of larvæ were found on the same day. The pupa was a very brilliant (5), but the lustre was silvery rather than golden, and the pupa looked unhealthy. About September 12 numbers of small Ichneumon flies emerged from the pupa case. Mr. E. A. FITCH kindly named the species for me; it was *Pteromalus puparum*, a common parasite of the Vanessidæ.

(2.) August 31, another pupa was found on the same nettle-bed near South Hincksey, but it was empty and perforated by the Ichneumon flies, which had already escaped. It had evidently been very golden and probably like the last.

(3.) The last pupa was found September 16 at Seaview (Isle of Wight) on a nettle-bed from which all the larvæ had disappeared, but upon which an evidently large company had been. The pupa was an exceptionally golden (3), but nevertheless it was dark in the parts which were not golden. The pupa looked unhealthy and did not undergo development; in the winter it had evidently been dead for a long time, and, breaking it in two, I found that it was completely filled with the larvæ of Ichneumon flies.

Hence the only exceptions I was able to find are readily explicable: they were all diseased, and doubtless the process of pupation was hurried on by their abnormal condition.

But, while it seems thus probable that the biological value of the gilded appearance was primarily due to its resemblance to glittering mineral surroundings, it is almost certain that in the course of time it has come to be used for other purposes. The most obvious of these is that it may act as a "warning" colour, indicating the possession of unpleasant qualities (taste or smell). But that this cannot be the original use is, I think, shown by the following considerations:—(1) The extreme specialisation of the means by which the colour is produced, and the fact that it is probably less effective than the crude combinations and startling contrasts of pigment colours upon which other warning colours depend; furthermore, belonging to such a very different type of colour, it does not follow the principle of a general resemblance between the various warning colours, which offers to insect-eating vertebrates as short and easy an educational career as possible. (2) The fact of the colour-relation itself, in which these gilded appearances have been shown to play a very important part. Now an adjustable colour-relation is the very highest and most complete means by which protective resemblance to surroundings can be produced, taking cognisance, as it does, of the inevitable differences between the surroundings of different individuals. But the object of a warning colour is to render its possessor as unlike its surroundings as possible, and hence it is something very essentially distinct from a colour which causes it to resemble its surroundings in the most perfect of all ways.*

Nevertheless there is nothing to prevent the one from changing into the other in the course of time. And the present condition of any animal is such a compound phenomenon, made up of so many modified and unmodified habits and structures connected with other older modes of life, interwoven with those which are especially related to its present needs, that it would not be surprising to find that a pupa which made use of the gilded appearance as a warning, in order to render it conspicuous, nevertheless retained something of the ancestral significance of the appearance in responding to some unusual stimulus caused by gilded surroundings. This suggestion is supported by the case of *Acræa esebria*, alluded to below.

* Since the above was written I have tested the golden pupæ of *V. urticæ* by offering them to insect-eating animals. There is, evidently, nothing distasteful about them, for the most scrupulous of all insect-eaters yet tested—a Marmoset—ate them readily one after the other. They were also freely eaten by insectivorous Birds. The experiments strongly support the view that the gilded appearance is of protective significance.—Sept. 9, 1887. E. B. P.

In order to test my suggestions as far as possible, I communicated with different naturalists in various parts of the world.

Mr. ROLAND TRIMEN kindly sent me the following letter from the Cape :—

"As regards gilded butterfly pupæ, I am unfavourably placed here for observation of them.

"We have only *P. cardui* and *Danais chrysippus* at this end of the country. The former varies much in the amount of gilding on the back and wing-covers, but I think that the three rows of dorsal tubercles are always brightly gilded. This larva does not seem particular as to site of suspension, apparently hanging itself indiscriminately to plants, walls, fences, etc.; but I have found it more frequently on walls, especially under the coping.

"The latter (*D. chrysippus*) has only a half-girdle (dorso-abdominal) of contiguous golden dots—set off by an immediately preceding black tuberculated ridge—and eight scattered golden spots about the head and thorax. This pupa is either green or pinkish, and sometimes of a tint combining both those colours. It is usually suspended to its food-plant.

"'I have not found the variable colouring of this pupa to accord with its immediate environment, though I have allowed the larvæ in confinement free choice of various convenient surfaces for pupation, with the view of ascertaining whether there was any relation between the green or reddish tint and the colouring of adjacent objects. It seems not improbable that this brilliant pupa stands in no need of special protection, but, like the imago (and apparently the larva also), is avoided by insectivorous animals.'—Extract from my forthcoming work, 'South African Butterflies.'

"Other Danaine pupæ appear to be exceedingly brilliant. Thus THWAITES (MOORE'S 'Lepidoptera of Ceylon,' p. 2) says: 'The suspended chrysalids' (of the Danainæ) 'are brilliantly metallic in colouring'; and BOISDUVAL ('Faune Ent. de Madag.,' etc., pp. 36, 37) describes thus the pupa of *Euplæa goudotii:* 'La chrysalide ressemble à une bulle d'or extrêmement brillante'; and thus that of *Danais phædone:* 'La chrysalide est . . . d'un vert doré brillant.'

"I should incline to the view that in this protected (distasteful) group of the Danainæ the conspicuously brilliant colouring of the pupæ *is* a warning signal of 'Not fit to eat!'

"Is it possible that the gilding in pupæ of other (not distasteful) Butterflies may originally have been acquired as protective mimicry of the brilliant Danaine ones?

"The only other South-African gilded Butterfly pupæ that I know of are those of the genus *Atella* (nearly allied to *Argynnis*). In these two species (which I only know by drawings and descriptions) the gilding (which in one is rather *silvery* than golden) is confined to spots on head and thorax, narrow borders of wing-covers, and dorso-abdominal raised spots bearing either pointed tubercles or thin spines. I have no information as to the objects to which these pupæ are usually attached.

"The pupæ of the Acræinæ (which, as you know, are a protected group of Butterflies), though (as far as I know) never gilded, are yet exceedingly conspicuous, their

ground-colour being white or yellowish, veined or streaked with black, and marked abdominally with bold orange-and-black spots, orange tubercles, or even (*Planema aganice*) long pink filaments!

"Very splendid gilding (evanescent after death) occurs in some of the Tortoise-beetles (Cassididæ). In these insects—almost circular in outline, flat abdominally, convex superiorly, with subdiaphanous extended margin—which rest exposed on leaves, there certainly *is* much resemblance to glittering dew-drops."

The evidence that *P. cardui* seems to prefer mineral surroundings is favourable. The Danainæ are evidently the group of pupæ which make use of this appearance as a warning, but, for the reasons given above, I think it is more probable that the protective colouring is ancestral, and its use as a warning is secondary, rather than that the development of the appearance took place in the reverse order. The fact that Mr. MANSEL WEALE proved the existence of colour susceptibility in the pupa of *Acræa esebria*—one of a group protected by the possession of an unpleasant taste—greatly supports the suggestion that the conspicuous warning appearance has been secondarily acquired.

It is very probable that, the gilded appearance having been once acquired, and closely resembling a very widespread and conspicuous mineral, the continued use of a small proportion of the colouring might be protective when the insect no longer pupated on mineral surfaces, because of the fact that the appearance does suggest the common mineral, whatever the position of the insect may be, and because of the resemblance to the glittering of dew upon leaves, as Mr. TRIMEN suggests. Thus the amount of gilding present upon the green form of *V. Io* may, perhaps, have this protective value.

Dr. FRITZ MÜLLER kindly wrote to me on the subject from Brazil as follows:—

"Leider kann ich Ihnen über goldige oder mit goldenen Flecken gezierte Puppen nur sehr wenig sagen; nur zwei derselben habe ich im Freien angetroffen: die von *Mechanitis lysimnia* und die von *Danais erippus*. Beide gehören zu der ungeniess-baren Gruppe der Danainen, und es ist der Goldglanz wohl ein Warnungszeichen. Die Raupe von *Mechanitis lysimnia* lebt an mehreren stachligen *Solanum*-arten in kleinen Gesellschaften, und an der Unterseite der Blätter der Futterpflanze hängen sich die Puppen auf; es gibt nichts Prächtigeres als diese ganz und gar im schönsten Metallglanze strahlenden, nicht selten zu 10, 12, oder mehr beisammenhängenden Puppen. Die Raupe von *Danais erippus* lebt an *Asclepias curassavica;* die Puppe habe ich nie an der Futterpflanze gesehen, dagegen oft an Bretterzäunen u. dgl. aufgehängt. Die Puppe ist grün und nur mit einigen goldenen Punkten geziert, von denen eine quere Reihe kleiner lebhaft glänzender Wärzchen am meisten in die Augen fällt.

"Andere Puppen mit Metallschimmer, der aber nie zu so hellem Goldglanz wird wie bei *Mechanitis,* habe ich nur in der Gefangenschaft gesehen, z. B., von verschiedenen *Adelpha*-arten. Ich glaube, dass hier der Metallglanz nicht als Warnung vor Ungeniessbarkeit, sondern als Schutz dient, weiss aber nicht in welcher Weise. Da

in unserem Urwalde Gestein nirgends zu Tage tritt, ist bei diesen grossentheils an Urwaldsbäumen lebenden Arten wohl kaum an Aehnlichkeit mit mineralischen Substanzen zu denken. Alle Puppen, die ich im Freien an Pflanzen zwischen Laub gefunden habe (z. B., *Morpho*, *Caligo*, *Prepona*, *Siderone*, *Catanephele*), sind grün, mit Ausnahme von *Acræa* (ungeniessbar), deren Puppen weiss sind, mit schwarzen Domen.

"Mit dem Bedauern, dass ich über Ihre Ansichten in Betreff der goldigen Puppen, die mir sehr annehmbar scheinen, so gut wie nichts aus eigener Erfahrung sagen kann, &c."

The use of the gilded appearance as a warning in *Mechanitis* seems to be very clear, and the fact that the pupæ hang in companies must of course greatly add to the effect, and this is probably the meaning of the habit (so common, for this reason, among many distasteful and conspicuous larvæ). It seems probable that the gilded spots of *Adelpha* are instances of persistence with protective value among changed surroundings and withdrawal from the substance originally imitated. From Dr. MÜLLER's letter it is quite clear that the resemblance to mineral substances cannot be of any protective importance in the Brazilian forests, but it does not therefore follow that such surroundings would not intensify the appearance even now. Thus *V. urticæ* in England has been shown to be rendered very brilliant by gilt surroundings, although in nature it can rarely receive such a stimulus, and the amount of gilding on it is very small or entirely absent. It is satisfactory that Dr. MÜLLER should consider my suggestion a probable one as to the biological significance of the gilded appearance.

My friend and pupil, Mr. E. A. MINCHIN, who has collected insects and observed very keenly in India for many years, informs me that the pupa of *Euplœa core* is exceedingly conspicuous, being covered with a brilliant metallic silvery appearance, and hanging from its food-plant in such a manner that it can be seen at a great distance. As the butterfly is exceedingly common, and is known to be protected by disagreeable properties, it is almost certain that the metallic appearance of the pupa acts as a warning. This, however, was the only instance of the use of this colour for such a purpose which had come under the observation of Mr. MINCHIN.

In conclusion, the balance of evidence given by experiment and observation is, I think, in favour of the view that the metallic appearance was originally of protective value from its resemblance to glittering minerals; that it has preserved its original significance amid change of surroundings; while in other cases it has come to be used for an entirely different purpose to render distasteful forms conspicuous.

Experiments upon Papilio machaon.

I received 11 almost mature larvæ from Mr. W. H. HARWOOD, of Colchester, on August 24, 1886. The following experiments were made. The eight largest larvæ

were selected August 24, and divided into two lots of four each, so that the sizes of the larvæ in the two lots were as equal as possible. Each lot was placed in a clear glass cylinder (of about 8 centimetres in internal diameter and 1·8 decimetre in height) with a roof and floor of brown paper. The food-plant (fennel) was confined to the lowest part of the cylinder and was very small in amount, and it was removed directly the larvæ ceased feeding, while the rest of the cylinder was completely filled with dead and brown twigs of a coniferous shrub and the dry brown stems of *Aconitum napellus* with the brown seed-vessels adherent.

The four larvæ in one cylinder were carefully blinded August 24, a process which could be very effectually carried out in this species, for the larvæ are very quiet, and, furthermore, all the ocelli are placed upon a distinct black patch; and when the latter is covered with an opaque varnish the ocelli must be also covered. On August 25 the larvæ were painted with varnish a second time, and on the 26th a third time. The other larvæ remained normal.

August 26, 9.20 P.M. One of the blinded larvæ had changed into a green pupa on the brown floor, but in close proximity to the green leaves of the food-plant, and one of the normal larvæ had also changed into a green pupa, which was fixed to one of the brown coniferous twigs; but here also the green food-plant was just beneath. The food-plant was then removed from both cylinders, as the larvæ had become full-fed.

In each cylinder four green pupæ were obtained, fixed to the brown stems or roof, or lying free on the floor. (One of these is figured in Plate 26, fig. 14.) These results surprised me very much, as I knew that there was a well-marked brown variety of the pupa not uncommon in this species.

Of the remaining larvæ two were placed (August 25) in a smaller glass cylinder (about 6 centimetres in internal diameter and 1 decimetre in height) covered with a single layer of green tissue-paper, and with a roof and floor of the same material, and with abundant food-plant.

The last larva was placed under exactly similar conditions, but was blinded (renewed as above).

This last larva and one of the former died, but the remaining larva pupated upon the green food-plant, and to my great surprise it produced *a distinct brown variety.* (This pupa is represented in fig. 15, Plate 26.) At first sight these results appear to be extremely startling, especially when it is considered that the experiments in this paper were directed towards the investigation of an adjustable imitative resemblance which, when present, forms the highest culmination of this method of protection. But, in the first place, it was probable that the green cylinder was more shaded than the other, and hence the production of the brown form might be accounted for, the species being simply susceptible to comparative darkness or illumination, and producing its corresponding dark or light variety in obedience to the respective stimuli; although the experiments showed that the ocelli have nothing to do with the susceptibility. Furthermore, the eight green pupæ were produced from the largest and

healthiest larvæ, while the remaining three were small, and of these only one lived to pupate. Hence an unhealthy condition, or even a stunted size, might become secondarily associated with one of the two varieties of a dimorphic species after the power of being influenced by the surroundings had been lost. Nevertheless, it is not necessary for the growth of some such association that the loss of susceptibility should have taken place, for it has already been shown that the gilded appearance and corresponding absence of pigment colours are associated with the presence of parasites in the pupæ of the Vanessidæ. It is clear from my experiments, and the previously quoted experience of others, that the susceptibility to corresponding colour influences has been lost in *P. machaon*, and Dr. FRITZ MÜLLER shows that it has also been lost in *P. polydamus*. On the other hand, the striking observations of Mrs. BARBER upon *P. nireus*, and of Mr. TRIMEN upon *P. demoleus*, prove conclusively that these species are highly susceptible to the influence of certain colours; and when it is remembered that both of the former non-sensitive species are dimorphic, and furthermore present in each case the two varieties, green and brown, which harmonise best with their surroundings, it appears probable that such dimorphism is the remnant of a former susceptibility which has, at any rate to a great extent, disappeared. Future experiments must finally decide whether the relative amounts of illumination produce any effect upon *P. machaon*, as Mr. HARWOOD believes, or whether either form of pupa exhibits a more or less constant relation to a healthy or unhealthy condition, or finally, whether the formation of either variety is the spontaneous result of individual variability.

Experiments upon Pieris brassicæ *and* P. rapæ.

Having read of Mr. T. W. WOOD's observations, and those of other naturalists, I was extremely anxious to obtain the larvæ of these species to investigate in the manner already described under *V. urticæ*, &c. I could only obtain single specimens in Oxford, and I thought that the experiments would have to be delayed for another season. However, just when the experiments on *V. urticæ* came to an end, on September 8, I went to Seaview, in the Isle of Wight, and there found the kitchen gardens ravaged by the larvæ of *P. brassicæ*, while those of *P. rapæ* were very abundant on mignonette. Accordingly, I made the experiments described below, and, although they were not as accurately or minutely conducted as those on *V. urticæ*, they yield some valuable results, and entirely confirm the previously adopted conclusion that the colour-effects are due to larval and not to pupal sensitiveness. Being away from my laboratory, and not expecting such an opportunity, it was, of course, impossible to carry out the experiments in the most satisfactory manner. The results obtained with the two species are described together, because they were, in nearly all cases, kept under similar conditions and were, in fact, often placed in the same cylinders. Furthermore, the results were remarkably uniform. When no locality is mentioned in any experiment it is understood that the included larvæ were captured at Seaview.

Both species are peculiarly adapted for experiments of this kind because of their quiet disposition and the great length of the period preparatory to pupation.

Before describing and classifying the results of the experiments upon the larvæ of *P. brassicæ*, it is necessary to construct a standard of the various degrees of colour assumed by the pupæ. In making such a list, it is necessary to take account of two features, each of which varies—the ground-colour, and the pigment patches and spots which are visible to the naked eye. Seven of the principal varieties are figured in Plate 26, figs. 24—30, all × 2.

(1) The normal form. In these pupæ the ground-colour is always more or less greyish from the abundance and relative size of minute black pigment spots which occupy depressions in the cuticle. They can often be distinguished with the naked eye on close and careful inspection; but their general effect is to produce the greyish appearance. The large black pigment patches and spots are nearly always abundant, and when the ground-colour is darkest the former also contribute towards a dark appearance by their especial size and number. The ground-colour may be of various tints—greyish-green, orange, yellow, or a peculiarly opaque-looking greyish-white. The amount of the grey colour always present subdues the differences between these tints, so that they resemble each other far more than the above description would seem to imply. The wings and under-side are always lighter than the rest of the surface, especially as regards the ground-colour, for the pigment patches are often very pronounced in these parts of the pupa. The following subdivisions are well marked, although transitional varieties occur:—

(α) The darkest forms with greyish-green, orange, yellow, or white ground-colour.

(β) Intermediate forms, with lighter ground-colour of the same tints, and smaller and fewer pigment patches.

(γ) The lightest of these forms, with ground-colour still greyish, but the pigment patches very small relatively to (α) or (β).

(2) The last subdivision passes into this variety, in which the ground-colour is an opaque-looking whitish-yellow, often with greenish areas on part of the surface, the pigment patches being very small. The greyish hue is lost because of the minute size of the dots in the ground-colour. Hence the effect is very light. The wings and under-side are lightest, and not so opaque as the dorsal and lateral surfaces; the pigment spots in these parts are small.

(3) A still more abnormal, very well-marked, variety, possesses a deep transparent-looking bluish-green ground-colour, in which the minute dots and the large patches are even less developed than in the last degree. An opaque whitish-yellow band, like the ground-colour in (2), occupies the anterior half of that part of the third abdominal segment which is seen dorsally, and extends on to the posterior part of the segment in front; and the dorsal surfaces of the abdominal segments behind the third are often mottled with the same colour. The median dorsal ridge is strongly marked in orange, interrupted in the abdominal region by opaque greenish-white, and the

supra-spiracular ridge and line are of this latter colour. The wings and under-side are pale transparent yellowish-white, with very small pigment patches.

The differences between the ground-colours of (1), (2), and (3) are very well-marked, whereas the predominant grey often masks the differences between the ground-colours of (α), (β), and (γ).

It is similarly necessary to construct a standard of the colours met with in *P. rapæ*. The colours of 10 of the chief varieties are figured in Plate 26, figs. 32–41, × 2, and in fig. 31, natural size.

(1) The darkest forms are plentifully dusted with minute black dots, producing a very dark grey appearance. There is very much pigment on the wings, and black patches are especially developed on the dorsal and sub-dorsal ridges or lines, and upon the rostrum. The ground-colour is hardly recognisable apart from the grey dusting, but can be seen clearly in certain parts of some pupæ, and is then usually of a faint pinkish or dull yellowish tint, or some mixture of these colours.

(2) Much less dark, due to the reduction in the amount of the minute dots and the black patches, which occur in the positions described above. Nevertheless, these pupæ are, as a rule, of darkish-grey appearance. The ground-colour is often more clearly recognisable, and is generally of the same tints as above, but the differences between the various tints are not generally well-marked until (4) is reached.

(3) Still lighter, but with sufficient of the grey dusting to obscure the tint of the ground-colour and to produce a grey or light-grey appearance. The black patches still occur in the same positions, but they are smaller; the same ground-colours are recognisable.

(4) Very light, with little or almost none of the grey dusting, so that the ground-colour is predominant in producing the general appearance. The black spots and patches are very slightly developed, and sometimes entirely absent, except for a few black points on the side of the rostrum, which is the last position in which traces of the pigment patches are retained. It is, however, common to find a slight, but distinct, speckling due to minute black points, but not sufficiently numerous to combine with the lighter ground-tint and produce a grey result. The ground-colours are much more distinct, as they are not dimmed, and are generally pinkish, yellowish, or faint greenish, or some combination of these. The latter colour is transitional into the brighter tints of the next degree.

(5) In certain pupæ the green ground-colour is sufficiently distinct to warrant their classification as a separate degree. All varieties of colour are met with, from the faint, scarcely perceptible, yellowish-green tinge of certain pupæ in the last degree to the more distinct and bright yellow greens arranged under this head, and finally up to a magnificent transparent emerald-green, which forms the culmination of the development of this tint as a ground-colour. There are also dull greens, and sometimes these pupæ are dusted with grey spots and have the black markings developed to a

considerable extent (such a pupa is figured Plate 26, fig. 31, natural size), but, as a rule, these pupæ are the lightest of all in both these respects. The lens, however, shows the existence of minute dots in all cases, although in the more extreme forms very few minute points can be detected by the naked eye, and there is no trace of the black markings even upon the rostrum. It is very common in the extreme forms of this degree, and in the lightest of the last degree, for the median and lateral ridges and the extremities of the body to be of a distinct pink tinge.

Series 1.—Larvæ subjected to Various Colours.

I. *Black.*

A.

On September 13, 10 mature larvæ of *P. brassicæ* and four of *P. rapæ* were placed in a cylinder 7 centimetres in internal diameter and 18 centimetres in height, lined entirely with thick blackened paper, and with a roof and floor of the same material. Thus the glass was entirely concealed, and the larvæ were everywhere surrounded by a black background, while light was almost completely excluded. In the following Tables the larvæ of *Pieris brassicæ* are indicated by the letters P. B., and those of *Pieris rapæ* by P. R. Periodical inspection gave the following data for estimating the length of the period preparatory to pupation, &c. :—

Sept. 13, 9.30 A.M.	Experiment began.	
„ 15, evening	2 larvæ, P. B., girdled	Stage III. at least 20–30 hours in these cases.
„ 16, 6.15 P.M.	1 P. B. pupated, and 2 girdled; 1 P. R. girdled	About 70 hours for the whole preparatory period of the 1 pupated.
„ 17, 7.30 P.M.	2 P. B. pupated, and 1 P. R.; 7 P. B. girdled	Between 90 and 100 hours for the whole period of the 2 pupated.
„ 18, 7.50 P.M.	6 P. B. and 1 P. R. pupated; 3 P. B. and 1 P. R. girdled	Over 100 hours for the whole period of some of these; others may not have begun Stage I. directly they were put in the cylinder.
„ 19, 8.47 P.M.	7 P. B. and 2 P. R. pupated.	

Results.—Except when it is otherwise stated, the pupæ were all compared together on January 23–26, 1887, and, as nearly the whole of them were thus placed together, the results are very trustworthy.

Eight pupæ of *P. brassicæ* were alive when the comparison took place.

5 were fairly crowded on the roof; of these. .	2 were (1), *α*, the ground-colour almost entirely grey.
	3 „ (1), *β*, 1 with a yellowish-green tinge, and 2 faintly orange.
3 were scattered over the side, towards the upper part, but not crowded	1 was (1), *α*, with a faint orange tinge.
	2 were (1), *β*, both greenish.

4 living pupæ of *P. rapæ* were similarly compared.

1 was with the group of 5 *P. brassicæ* described above, and it was a	light (3), with a yellowish-grey ground-colour and a rather small amount of grey dusting.
3 were scattered over the side with the 3 *P. brassicæ*, and of these	2 were (3), typical, and of the usual light-grey colour caused by the abundant sprinkling of minute dots over the light ground-colour, which is apparently very pale pinkish in this case, but very hard to determine.
	1 was (4), with very little pigment and a dim yellowish ground-colour.

The effect of the dark surroundings is thus much more manifest in the pupæ of *P. brassicæ* than in *P. rapæ;* nevertheless, the latter are very different from those produced in white surroundings. It is very strange that the results of a deep black surface exposed to daylight should be darker than those produced by the same surface in darkness, and yet this appears to be the case, for the pupal colours on the tarred fences are much darker than those described above. At the same time, the pupæ on the fence were generally shaded in cracks and corners, and the fence itself was in a shady lane, but the amount of light must have been in all cases far larger than in the cylinder. Such results are the reverse of those obtained in the case of *Vanessa urticæ.*

B.

September 11, at 7.30 P.M., 10 nearly mature larvæ of *P. rapæ,* found on mignonette at Seaview, were placed in a cylinder (6·7 centimetres in internal diameter and 2·24 decimetres in height) lined for rather more than half of its internal circumference with opaque blackened paper, and with a roof and floor of the same material. Some of the food-plant was also included. No notes were taken as to the times of pupation, &c.

Results.—10 pupæ were obtained, of which—

5 were on the black roof, and of these. . . .	1 was (2), a little lighter than usual; yellowish-pink.
	4 were (3), 1 considerably lighter than normal and greenish; 3 normal and pinkish.
4 were on the clear side of the cylinder, but so high up that they came against the inflected edge of the roof, and of these	3 „ (1), not very black for this stage; 1 distinctly pinkish, the others chiefly grey.
	1 was (3), rather lighter than normal, and yellowish-pink ground-colour.
1 was fixed on to the background near to the roof, and it was a	(1), typical pinkish ground-colour as far as it could be seen.

These pupæ are decidedly darker than those of the preceding subdivision, and yet they were freely exposed to light: on the other hand, they are less dark than the wild larvæ found on the tarred fences, which, although shaded (in my own observations), were probably in a stronger light than that to which the pupæ of this subdivision were exposed. These results seem to show that, at any rate in *P. rapæ*, the stronger illumination of a black surface tends towards the production of stronger effects, just as would be the case with a white or green surface, while the direct white light falling on the larval surface produces no antagonistic effects.

C.

September 15. Four pupæ were found at this date upon a black tarred fence in a shaded lane at Seaview, and they were compared with the other pupæ examined on this date. All were (1), very dark; two pinkish, and two so dark that the ground-colour could hardly be made out, but probably yellowish. These results are very uniform, and show the influence to have been very strong. It has already been mentioned that the pupæ were in most cases concealed in angles and corners, &c., and this was also true of the succeeding pupæ.

D.

October 5.—Three pupæ of *P. rapæ* were found October 5 on a black tarred fence in a shaded lane at Seaview. All were (1); one very black, one normal, and one rather light for this degree and distinctly pinkish: the others being very dark grey, so that the ground-colour was almost entirely concealed, but apparently pinkish in one pupa and yellowish-pink in the other. These results are very uniform and highly protective.

E.

Mr. W. H. Harwood kindly sent me 11 pupæ of *P. rapæ* found upon tarred palings, and all of these were (1); five extremely black, two normal, and one very grey rather than black; three dead, but apparently very dark as far as could be ascertained from the large amount of pigment on the pupal wings. The ground-colour seemed to be pinkish in all cases. These results are exceedingly uniform, and show the very strong effect of the black surface.

In concluding the effects of black, it will be of interest to give a tabular analysis of the effects of this background, in various degrees of illumination, upon *P. rapæ*:—

Degrees of colour.	Dark (1)	(1)	(2)	(3)	(4)	(5)
I., A. Black background in darkness . . .	..	..	..	3	1	..
„ B. „ „ somewhat shaded .	..	4	1	5	..	..
„ C. } „ „ less shaded . . {	4	..	..	..	..	..
„ D. }	1	2	..	..	..	..
„ E. „ „ probably less shaded	5	6	..	..	..	..

This analysis seems to prove almost conclusively that the stronger illumination increases the influence of the black surface upon the larvæ. At the same time, it must be remembered that A. and B. were larvæ which had been kept for some time in the cylinders, whereas C., D., and E. had been under more normal conditions, as the pupæ were found wild.

The relation of the effect of black surfaces to those of other colours will be shown later in an analysis of the colours of all pupæ which had been exposed to such surroundings during the whole of the preparatory period.

II. *White.*

A. *In almost complete darkness.*

On September 9 a large number of mature larvæ of *P. brassicæ* and a few of *P. rapæ* were placed in a light-blue cardboard box, of which the internal surface was white. (The length was 3 decimetres, width 1·1 decimetre, and the depth 7·7 centimetres.) The cardboard was thick and opaque, so that light could only enter to a slight extent between the lid and the box, and perhaps at the angles. The larvæ were thus exposed to a white surface in almost complete darkness. No notes were taken as to the times of pupation, &c.

Results.—When the comparison took place there were 41 living pupæ of *P. brassicæ*, and, of these, 20 were fixed to the roof, being greatly crowded in an irregular group 1 decimetre long and 7 centimetres in its greatest width.

Of these 20 pupæ	4 were	(1), *a*, very dark indeed ; 3 being very faintly orange, and 1 almost entirely grey, but slightly greenish.
	14 „	(1), *β*, 5 being faintly orange, and the others more or less yellowish-green, but the grey tints predominant in all.
	2 „	(1), *γ*, the ground-colour yellowish-green, mottled with deeper green. Black patches small.
2 pupæ were fixed to the roof close together, but at a distance from those described above.	1 was	(1), *β*, faintly orange.
	1 „	(1), *γ*, distinctly greenish and less grey than usual; the black patches rather more developed than usual.
1 pupa was isolated on the roof, and was		(1), *γ*, yellowish, mottled with greenish; typical.
3 pupæ had been previously taken off the roof, or had fallen off it; position unknown	2 were	(1), *β*, pale greyish-orange ground-colour; 1 of them with a rather deeper tint, and mottled with greenish.
	1 was	(1), *γ*, greyish-green; typical black patches.

15 pupæ were crowded on one end of the box and on the adjacent part of one side, but not at a greater distance than 4 centimetres from the end. None were close to the bottom of the box, but nearly all were crowded along the top of the end and side.

Of the 15 pupæ, 2 were (1), *a*, very dark; 1 faintly orange, the other greenish-yellow.

13 „ (1), *β*, 5 greenish, 2 very pale ochreous, 2 yellowish, 2 faintly orange, 2 yellowish-green. All except the first five were rather light for this degree, both as to the amount of grey dusting and the large black patches, but they were not light enough for (1), *γ*.

There were only two pupæ of *P. rapæ*, of which one was in the group of 20 *P. brassicæ* described above, and it was a (4), with very little pigment and a pale-yellowish ground-colour. The other pupa was isolated in one of the corners where two of the sides met, opposite to the end where the 15 pupæ of *P. brassicæ* were crowded. It was (2), typical, with the ground-colour almost entirely grey, but apparently faintly yellowish also. Hence it is clear that the white surroundings had produced very little effect upon the larvæ, which, indeed, was to be expected, considering the almost complete darkness. There is no doubt, however, that the pupæ of *P. brassicæ* are not as dark as those formed in the dark (I., A.) upon a black surface, and hence some effect seems to have been caused by the exceedingly feeble amount of light which penetrated. The two pupæ of *P. rapæ* differed widely, one being the form commonly occurring on white or light surfaces, the other much darker.

B. *Very strongly illuminated.*

September 11, 9.30 P.M.—Many larvæ of *P. rapæ* were placed in a cardboard box (2·1 decimetres in length, 1·22 decimetre in width, and 8·5 centimetres in depth) which was lined with white glazed paper, and with a clear glass front, directed, as in the other cases, towards a strong light and close to a north-east window. The larvæ, some of which were apparently mature, had been found upon mignonette at Seaview, and some of this food-plant was also included. No notes were taken as to the times of pupation.

Results.—19 living pupæ were obtained in this experiment, and of these—

3 were fixed to the glass front, near together, and near to the white sides of the box; and of these. . . . . 2 were (4), very little pigment, 1 with a pale-pinkish, the other a yellowish-pink ground-colour.

1 was (5), almost no pigment; a pale, but bright, yellowish-green ground-colour; the ridges and extremities of the body pale pink, as is common in green varieties.

13 pupæ were thickly crowded along the angles made by the roof and adjacent parts of the two sides with the back, and of these . .	2 were (3), very light for this degree, 1 pinkish and the other yellowish.
	10 „ (4), very little pigment on all but 1, and this 1 but little more than normal; 4 pinkish, 4 yellowish-pink, and 2 yellowish-white.
	1 was (5), very little pigment; pale, but distinct, yellowish-green ground-colour, with pink tips and ridges.
3 pupæ were isolated on the roof, sides, &c.; of these	2 were (4), both pinkish: 1 typical, 1 with very little pigment.
	1 was (5), little more pigment than usual; very pale yellowish-green ground-colour.

The strong effect of the white back-ground in producing light-coloured pupæ is well seen in the above descriptions. It is noteworthy that the degree of colour represented by (4) harmonises far better with this background than that represented by (5). Hence the (5) were of a very pale-greenish colour, and not conspicuous as well-marked green varieties would have been. Furthermore, the (4) were in nearly all cases very deficient in pigment, so that in this respect they were quite equal to normal (5).

C. *Strongly illuminated, but not equal to* B.

A few larvæ of *P. rapæ* were made use of in some experiments to test, by blinding, whether the influence of surrounding colours acts through the ocelli. Two glass cylinders of equal size (8·2 centimetres in internal diameter and 1·81 decimetre in height) were covered externally with a single layer of white tissue-paper, and with a roof of white glazed paper, and a floor of ordinary white paper. The cylinders were placed in a fairly strong light, several feet from a north-east window. The experiment was conducted as follows:—

Dates.	α. Blinded.	β. Normal.
Sept. 17, 10 P.M. .	Experiment began	Experiment began.
„ 18, 8.40 P.M.	1 larva, which had been found in Stage I. or II. on a plain wood fence at Bembridge, was girdled; another, still feeding, having been found on mignonette at Seaview	2 larvæ had both gone up the side and were sitting motionless; food removed; they had been found on mignonette at Seaview. Another, added at this time, found in Stage II. under the cement coping of a gate pillar at Spring Vale.
„ 19, 9.5 P.M. .	No further change	2 larvæ mentioned above were girdled.

No further notes were taken, but all five larvæ produced living pupæ.

Results.—(α) Of the two pupæ, one was fixed to the roof and the other horizontally to the side just below : both were (3), but light for this degree ; one distinctly pinkish, and one faintly yellowish-green, the latter very small and dwarfed.

(β) Of the three pupæ, one was fixed to the roof, one about halfway up the side, and one near the bottom of the side ; all were (4), one faintly pinkish, one yellowish and dark, intermediate between this degree and (3), and one yellowish and much dwarfed. The pigment patches and dots were normal in two of the pupæ.

Although the two blinded larvæ produced rather darker pupæ, the differences were *very* slight indeed, and are quite insufficient to support the conclusion that the ocelli represent the part of the larva which is sensitive to these influences. The larvæ remain quiet when blinded, like those of *P. machaon*, and are very well suited for this method of investigation. The effects of white surroundings are shown in the pupal colours.

D. *Strongly illuminated, but not equal to* B.

A little later another similar experiment was made, the same cylinders being used. Four larvæ found on mignonette were placed in one cylinder, and three blinded larvæ, also found on mignonette, were placed in the other. No notes were taken as to suspension, &c. Seven pupæ were obtained.

Results.—Of the four pupæ which were produced from the normal larvæ—

1 was fixed to the roof, and was a	(4), normal, brownish-pink ground-colour.
3 were fixed horizontally to the side just beneath the roof, and of these	2 were (4), normal, both very faintly pinkish.
	1 was (5), of a pale dull green and more grey than usual, and more of the pigment patches, so that, as far as pigment is concerned, it would have been a somewhat dark (4).

Of the three pupæ which were produced from the blinded larvæ—

1 was fixed to the roof, and was a	(4), yellowish, with rather more of the pigment patches than usual ; grey dusting normal.
1 was fixed horizontally to the side, just beneath the roof, and was a	(4), very pale yellowish-pink, with an almost complete absence of pigment, except upon the rostrum ; so also very little grey dusting. Altogether, considerably lighter than normal.
1 was fixed horizontally about halfway down the side, and it was a	(3), with a distinct dull-greenish ground-colour ; it much resembled the (5) of the normal pupæ, only the grey dusting predominated, so that the green was largely concealed. Dusting normal for (3), black patches rather less than usual.

These results negative the view that the ocelli represent the sensitive organs sought for, for the two sets of pupæ were, on the whole, as equal as possible. The latter set of three pupæ included one lighter than any of the other set, and two somewhat darker; but the differences were slight in all cases. The larval heads remained in proximity to their respective pupæ, so that the success of the blinding could be tested afterwards, and the varnish, when examined with a lens, appeared to completely cover the ocelli and the surrounding area.

The light pupæ produced by the white surfaces are well seen in the 12 pupæ of these experiments.

It will now be interesting to give a tabular analysis of these results, showing the effects of white surfaces with different degrees of illumination in the case of *P. rapæ*.

Degrees of colour.	(1)	(2)	Dark (3)	(3)	Light (3)	Dark (4)	(4)	Light (4)	Pale (5)	Deep (5)	
II., A. White surface in almost complete darkness	..	1	..	..	..	..	..	1	..	..	= 2
„ C. White surface in strong	..	..	..	..	2	1	2	..	..	..	= 5
„ D. illumination	..	..	..	1	..	1	3	1	1	..	= 7
„ B. White surface in very strong illumination	..	..	..	..	2	1	1	12	3	..	= 19
Total	..	..	..	..	..	..	..	..	..	..	33

This analysis shows well the increasing effect produced by increasing illumination, for the description of the apparatus used in C. and D., on the one hand, and in B. on the other, indicates that the differences between their degrees of illumination must have been very great. Furthermore, the background of B. was entirely composed of an intensely white and strongly reflecting surface, while in C. and D. the roof (and to some extent the floor) alone possessed this property to a considerable extent, the sides of the cylinder being composed of white tissue-paper. On the other hand, there was a large amount of food-plant which remained until after pupation had taken place in B., while only a small quantity was placed in the cylinders, and this was removed when the larvæ had ceased to feed.

III. *Red.*

A.

On September 13, 15 mature larvæ of *P. brassicæ*, and the next day many larvæ of *P. rapæ*, were placed in a cylinder 8·2 centimetres in internal diameter and 17·8 centimetres in height, lined internally with deep-red opaque paper for about three-quarters of its circumference, and with a roof and floor of the same substance. The experiment was conducted as follows. This and the following colours made use of in these experiments are shown on Plate 26, figs. 16–21 inclusive.

Sept. 13, 9.15 A.M.	Experiment began.	
,, 14, 8.45 P.M.	Many larvæ of P. R. added.	
,, 15, EVENING	Many P. B. girdled	Stage III. at least 20–30 hours in these cases.
,, 16, 6.25 P.M.	2 P. B. pupated, and about 9 girdled; 1 P. R. girdled	About 70 hours for the whole period of these 2 larvæ.
,, 17, 7.35 P.M.	6 P. B. pupated (2 of them deformed); 1 P. R. pupated; 6 P. B. girdled	About 100 hours for the whole period of some of these; others may not have begun Stage I. at once.
,, 18, 8.35 P.M.	11 P. B. pupated, and 1 P. R. pupated; 1 P. B. and 1 P. R. girdled	
,, 19, 9.10 P.M.	12 P. B. pupated, and 2 P. R. pupated.	

Results.—11 pupæ of *P. brassicæ* were alive on January 23, when the comparison was made, and—

Of these, 7 were rather crowded upon the roof.

Of the 7 . . . . . 4 were (1), *a*, very grey and dark, but 2 of them showing a faint orange tinge, and the other 2 apparently greenish, but the grey is entirely predominant.

2 ,, (1), *β*, greyish-white, mottled with green.

1 was (1), *γ*, greyish-green, with opaque whitish marks as in (3) degree of colour. This form is transitional into (3), retaining the greyish tinge of (1), although subdued so that the green is well-marked, while the pigment spots are small for (1).

2 were isolated on the clear glass front of the cylinder, and of these . . . 1 was (1), *a*, very dark; faint orange tinge.

1 ,, (1), *β*, greyish-green, with some white.

2 were isolated on the red background, fixed in a horizontal position just beneath the roof, and of these both . were (1), *β*, 1 being faintly yellowish, the other apparently yellowish-green, but with the grey predominant.

Hence the red background produced very dark results in the case of *P. brassicæ*, for out of the 11 pupæ there is only a single (1), *γ*, while there are five of the darkest forms (1), *α*. The pupæ of *P. rapæ* were all dead.

B.

Mr. HARWOOD also sent me 35 pupæ of *P. rapæ* found upon red brick walls.

Of these, 21 were (1), 12 very dark indeed, and apparently with a dull-pinkish ground-colour; 9 normal, with the same tinge.

2 ,, (4), very grey, but with hardly any black patches; a yellowish and a pinkish variety.

12 pupæ were dead, and, as far as I could judge, they were mostly very dark varieties.

Hence the pupæ were as a whole extremely dark, like those of *P. brassicæ*. It should be noted that many of them may have been upon the mortar, or in dark corners, under coping, &c., and doubtless the red colour of the bricks was very variable, depending upon the age of the walls.

Since writing the above, I have had an experience which confirms my hesitation in accepting the above results as necessarily following from the red colour. I had long noticed a large number of pupæ of *P. rapæ* upon Keble College chapel, and when I removed them in order to describe the colours for this paper I carefully observed and noted the places of pupation. After I had collected 20 or 30 pupæ I found it useless to proceed, as they had almost without exception been attacked by Ichneumon flies and were dead and faded. I noticed, however, that not a single pupa was attached to the red brick wall of the chapel, but to the mortar immediately beneath the projecting stone-courses, or upon the overhanging surfaces or hollows of the stone itself.

IV. *Orange.*

A.

On September 14, 12 mature larvæ of *P. brassicæ* and 10 of *P. rapæ* were placed in a cylinder 8 centimetres in internal diameter and 18 centimetres in height, and lined internally with deep-orange opaque paper for about two-thirds of the circumference, and with a roof and floor of the same material. Periodical examination produced the following results:—

Sept. 14, 10 A.M. .	Experiment began.	
„ 16, 6.5 P.M. .	4 P. B. pupated, and 1 P. R.; 8 P. B. girdled, and 3 P. R. girdled	The whole period for the 5 pupated must have been less than 56 hours if it began when they were placed in the cylinder.
„ 17, 7.25 P.M.	7 P. B. and 2 P. R. pupated; 5 P. B. and 3 P. R. girdled.	
„ 18, 8.35 P.M.	12 P. B. and 4 P. R. pupated; 1 P. R. girdled.	
„ 19, 9.15 P.M.	12 P. B. and 5 P. R. pupated; 2 P. R. girdled.	

Results.—All the 12 pupæ of *P. brassicæ* were alive when they were compared, and of these eight were rather crowded on the roof.

Of the 8 pupæ	2 were (1), β, both yellowish, and not so grey as usual in this degree.
	6 „ (3), very typical forms.
1 pupa was fixed in a horizontal position on the clear glass side, but so high up that it came against the orange background formed by the margin of the paper forming the roof. It was	(3), an unusually deep bluish-green on almost the whole of the dorsal surface.
1 pupa was fixed horizontally on the clear glass just below the last. It was . .	(3), typical.
1 pupa was fixed vertically on the clear glass about ⅓ from the roof. It was .	(2), with rather larger black spots than usual.
1 pupa was fixed vertically on the orange background, but high up and close to the roof. It was	(3), typical.

The five living pupæ of *P. rapæ* were also compared at the same time, and—

Of these, 2 were fixed horizontally on the clear glass side, but high up, so that they came against the orange background formed by the margin of the paper roof (as above).	
The two pupæ were both . . .	(5), with a pale transparent yellowish-green ground-colour; very little pigment on 1 pupa, and perhaps rather more than usual on the other.
1 was fixed to the roof with the 8 *P. brassicæ* described above. It was a	(4), typical, with a distinct, but very pale, yellowish-green ground-colour.
1 was fixed vertically to the clear glass about $\frac{1}{3}$ from the roof, and it was a	(4), typical; very faintly yellowish ground-colour.
1 was fixed on the orange background close to the roof, and it was a . . .	(5), a beautiful bright-yellow green, with hardly any pigment.

The strong effects of the orange background in the prevention of pigment formation and in the production of a green ground-colour are very interesting and remarkable, for the results, although so well-marked, are certainly not especially protective. It is also most interesting that *P. brassicæ* and *P. rapæ* should have been influenced so uniformly. The bright green variety of *P. brassicæ* chiefly formed by the use of this background is represented in Plate 26, figs. 29 and 30, × 2.

B.

About October 13 a few larvæ of *P. brassicæ,* which, I believe, were found upon *Tropæolum;* and a few *P. rapæ,* were placed in a cylinder lined with orange paper of the same size and arrangement as that already described. No notes were taken as to the dates of pupation.

Results.—Two pupæ of *P. brassicæ* were obtained:

Of these, 1 was isolated on the clear glass front, and was	(1), β, normal; somewhat pale ochreous ground-colour.
1 was isolated on the background, very low down; it was	(1), γ, rather unusually greyish for this degree, but deep-green anteriorly and opaque-looking whitish-green posteriorly; the usual small black patches.

1 pupa of *P. rapæ* was isolated upon the clear glass side, and it was a (4), rather dark for this degree, and possessing a dull-yellowish ground-colour.

The same results of the orange background are seen in these pupæ, but they are not equal to those described in Division A.

V. *Yellow.*

A.

On September 14 four mature larvæ of *P. brassicæ* and four of *P. rapæ* were placed in a cylinder 6 centimetres in internal diameter and 10 centimetres in height, lined internally with light-yellow opaque paper for about three-fourths of its circumference, and with a roof and floor of the same colour. Periodical inspection gave the following results :—

Sept. 14, 10.25 A.M.	Experiment began.	
„ 15, 10.25 P.M.	2 P. B. girdled for at least 12 hrs., as they were so in the morning when inspected.	
„ 16, 6.30 P.M.	2 P. B. pupated lately, and 1 girdled, and also 1 P. R.	Whole period less than 56 hrs. if it began when they were placed in the cylinder.
„ 17, 7.40 P.M.	3 P. B. pupated and 1 P. R. girdled.	
„ 18, 8.30 P.M.	3 P. B. and 1 P. R. pupated, and 2 P. R. and 1 P. B. girdled.	
„ 19, 9.13 P.M.	4 P. B. pupated and 2 P. R. pupated; 1 P. R. girdled.	

Results.—Three pupæ of *P. brassicæ* were alive when all were examined and compared :—

1 on the roof was . . . . . (1), ♀, typical; yellowish, with the faint greyish tinge and small black patches.

2 were scattered over the side, and of these 1 was (2), typical.
1 „ (3) „

Two living pupæ of *P. rapæ* were similarly compared,

1 being on the roof; it was a . . . . . (5), with a distinct, but dull-green, ground-colour, much dusted with grey dots, and an amount of pigment on ridges, rostrum, &c., which would be typical of (3).

The other pupa was isolated on the clear side of the cylinder, and it was a . . . . . (3), with a rather distinct yellowish ground-colour, and rather less grey than usual in this degree.

Thus the effects of yellow appear to be in the same direction as those of orange, although, as far as the evidence goes, the influence does not appear to be equally strong.

VI. *Green.*

A.

September 14.—Four larvæ of *P. brassicæ* and one of *P. rapæ*, and later four more of the former and four of the latter, were placed in a small glass cylinder (6 centimetres in internal diameter and 8·5 centimetres in height) completely covered externally with one layer of green tissue-paper, and with a roof and floor of the same material. Notes were taken at the following dates :—

Sept. 14, 9.15 P.M. .	Experiment began.	
„ 15, EVENING .	1 P. B. girdled.	
„ 16, 7 P.M. .	4 P. B. girdled, and the P. R. pupated some time 4 more P. B. and 4 P. R. added	The P. R. must have passed about 40 hrs. in the period if it began when larva was placed in the cylinder.
„ 17, 7.25 P.M. .	3 P. B. pupated, and 1 P. R.; 3 P. B. and 1 P. R. girdled	Under 72 hrs. in the period if it began with the experiment.
„ 18, 8.30 P.M. .	6 P. B. pupated, and 1 P. R.; 2 P. B. and 1 P. R. girdled	Under 48 hrs. for some of these if the period began with the experiment.
„ 19, 8.55 P.M. .	6 P. B. pupated, and 2 P. R.; 2 P. B. girdled.	

Results.—Seven living pupæ of *P. brassicæ* were obtained :—

6 were crowded on the side near the roof,
and of these . . . . . 5 were (2), all with the characteristic opaque yellowish ground-colour, mottled with green, and small black patches and spots. One was yellower than the others, with less of the green mottling.
1 was (3), rather greyer-green than usual, and rather larger black patches.

1 pupa was more isolated, and an outlying member of the group described above: it was (1), β, with a rather brighter and more distinct yellowish-green ground-colour than usual, because the grey was less pronounced.

Two living pupæ of *P. rapæ* were similarly compared, both being in the group of six *P. brassicæ* described above; and

Of these, 1 was a (3), light for this degree, with a faint yellowish-green ground-colour, and much less of the grey dusting than usual posteriorly; normal anteriorly.
1 was a (4), with very little pigment and very pale pinkish ground-colour.

It is very remarkable that the green surroundings should have shown less influence than orange or yellow in the production of varieties which by their colour are especially protected upon the first-named colour. It must be remembered, however, that the conditions of experiment were different, tissue-paper being used in this case, and highly illuminated opaque reflecting surfaces in the former. Nevertheless, tissue-paper has been shown to produce marked effects with *V. Io*, and it certainly made a bright green background. And here, although the effects seem small when compared with those of orange, they are in reality considerable, and are all in a protective direction.

B.

September 15.—10 larvæ of *P. brassicæ* and 13 of *P. rapæ* were placed in a glass cylinder (7·5 centimetres in internal diameter and 17·25 centimetres in height) completely covered externally with one layer of green tissue-paper, and with a roof and floor of the same material. The *P. rapæ* had been found upon mignonette, and were mostly full-fed, but after September 16 they were fed upon cabbage. The following notes were made :—

Sept. 15, EVENING .	Experiment began.	
„ 16, 7 P.M.	5 P. B. girdled.	
„ 17, 7.30 P.M.	2 P. B. pupated, 6 girdled; 2 P. R. girdled	Under 48 hours' period for these 2 if it began with the experiment.
„ 18, 7.52 P.M.	8 P. B. pupated, 1 girdled; 1 P. R. pupated, and 2 P. R. girdled	So also under 72 hours for these additional ones.
„ 19, 8.52 P.M.	9 P. B. pupated, 1 P. R. pupated; 3 P. R. girdled, and 1 P. R. making girdle.	

Results.—Nine pupæ of *P. brassicæ* were obtained, and—

Of these, 1 was on the roof, and was . . . . . (1), β, black patches normal, dusting rather less, and ground-colour rather more distinct than usual; yellowish-green, inclining to very pale orange in places.

7 were on the side, fairly crowded, and all upon the upper $\frac{1}{4}$ of the height of the cylinder; of these . . . . 2 were (1), β, 1 pale-greenish and 1 very pale orange; dusting less than usual; black spots normal on former, less than normal on latter.

4 were (2), almost normal, but the ground-colour a *little* greener than usual.

1 was (3), typical.

1 was more isolated on the side, and was . . . (2), with normal ground-colour, but the black spots more developed than usual.

Eight living pupæ of *P. rapæ* were similarly compared, and—

Of these, 2 were on the roof, of which . . . . 1 was a (5), very little pigment, and very pale greenish ground-colour; and

1 „ (4), very little pigment, and a pale yellowish-pink ground-colour.

1 pupa was on the side near the top, in the crowd of 7 *P. brassicæ* described above, and it was a . . . . . (4), typical, with a greyish-yellow ground-colour.

5 pupæ were more isolated on the side, and of these . . . . . 2 were (3), but both light for this degree, 1 with a yellowish-pink ground-colour, and 1 with a dull, but distinct, greenish ground-colour.

2 were (4), 1 typical, 1 with hardly any pigment; the ground-colour faintly yellowish-pink in both.

1 was (5), of a distinct green ground-colour, but dull for this degree, and with the greyness and black patches of a light (3).

These results are very uniform with those of Division A. The more numerous *P. rapæ* in this division show that the green surroundings have some considerable effect, as one-fourth of the pupæ were the green form (5). The bright yellowish-green variety of *P. brassicæ*, which was chiefly formed by the use of this background, is represented in Plate 26, fig. 28, × 2.

C.

September 13.—20 larvæ of *P. brassicæ* and 10 of *P. rapæ* were placed in a shallow wooden box (2·26 decimetres long, 1·3 decimetre wide, and 5·2 centimetres deep: all internal dimensions) lined internally with thick paper tinted with a pale bluish-green colour, which became whiter owing to the pigment being removed in many places. The box was made to stand on one of its long sides and covered with a sheet of clear glass, and it was placed close to the window, so that a strong north-east light was directed into the interior. Notes were taken at the following hours :—

Sept. 13, 9.50 P.M.	Experiment began.	
„ 16, 6.5 P.M.	1 P. B. pupated; 5 girdled. The box was inclined backwards at an angle of about 45°, so that the roof was illuminated to an extent equal to that of the rest of the box, for the larvæ tended to collect on the roof for pupation.	Under 72 hours for the 1 pupated, if the period began with the experiment.
„ 17, 8.15 P.M.	4 P. B. pupated, 8 girdled; 3 P. R. girdled	Under 95 hours for these additional ones.
„ 18, 9.15 P.M.	7. P. B. pupated, 7 girdled; 3 P. R. pupated and 2 P. R. girdled.	
„ 19, 9.25 P.M.	10 P. B. pupated, 2 girdled; 3 P. R. pupated and 2 P. R. girdled.	

Results.—11 living pupæ of *P. brassicæ* were obtained.

7 were crowded in a corner of the roof, and all . . . . . were (1), β, with normal black patches, but the ground-colour a peculiar greenish-white, very opaque-looking, much dusted with grey, as usual: with a slight orange tinge in 1 pupa, and 2 pupæ rather more yellowish-green than the others.

1 pupa was isolated on another part of the roof, and . . . . . was (1), β, like the others, and especially resembling the 2 last described.

3 pupæ were isolated on the clear glass front, and of these . . . . . 2 were (1), *a*, one of them faintly orange, the other pale greenish, rather unusually distinct, because the grey dusting, although very pronounced, was locally collected into bands and patches, leaving the colour comparatively undimmed between them.

1 was (1), β, resembling the 3 last described of this degree, only a brighter colour than any others, because of the comparative absence of the grey dusting: a bright yellowish-green.

Three living pupæ of *P. rapæ* were similarly compared, and—

Of these, 1 was isolated on the side of the box, and it was a . . . . (4), pink ground-colour, and very little pigment.
2 were isolated on the glass front, and of these . . . 2 were (3), one typical, with a yellowish ground-colour; the other very light for this degree, with a pinkish ground-colour.

The influences in this division seem to have been much weaker as far as the prevention of pigment formation is concerned than in the two preceding experiments, and this is probably on account of the colour employed. The green, although bright, was of a very bluish delicate tint, and was easily removed or rendered paler. On the other hand, there was a special peculiarity about the ground-colour of the majority of the pupæ of *P. brassicæ* (one of which is represented in Plate 26, fig. 27, ×2) which harmonised well with these surroundings, and appeared to indicate a power of special colour adaptation to minute differences or peculiarities in the surroundings which was not seen to an equal extent in any of the other experiments.

D.

A mature larva of *P. rapæ* was found upon cabbage in a garden at Oxford about the beginning of September, and was placed in a small cylinder covered with one layer of green tissue-paper, and with a roof and floor of the same substance. Mignonette was introduced as the food-plant, but the larva, without feeding, pupated upon one of the leaves. The pupa was a deep green (5), but with an unusual development of the black markings for this stage. The markings were present to the same extent as in a typical (3), although the grey dusting was very deficient. The distinct and bright ground-colour left no doubt of the real degree of the pupa. This pupa is represented in Plate 26, fig. 31, natural size.

E.

October 5, a large number of pupæ were found on a very deep-green gate in a shaded lane at Seaview, but the vast majority contained the larvæ of parasitic Hymenoptera, and had dried up when the comparison was made.

It is also to be noticed that the pupæ were nearly always concealed in the shadows of the mouldings and under the overhanging parts of the framework, &c.

Only 6 pupæ remained alive when the comparison took place.

Of these, 1 was (1), typical, yellowish-pink as far as the ground-colour could be seen through the abundant pigment.
2 were (3), 1 typical and apparently faintly yellowish-pink, the other light for this degree and distinctly pinkish.
3 ,, (4), all about normal, and yellowish-pink.

There must have been quite 20 more which had died, and there certainly was not a (5) among them, for I remember being astonished at the time at the small effect produced by the green background. One *P. brassicæ* was found at the same time, which also died from the same cause, but it was a distinct (1), and probably the common (1), *β*.

It is probable that these surprising results are due to the peculiarly deep and strong colour of the paint, against which the usual bright transparent yellowish-green, or the delicate emerald-green of the (5) degree of colour, would have been at least as conspicuous as the darker varieties which were actually found. There was certainly a great contrast between the colour of the gate and the more delicate green tints used in the preceding experiments.

VII. *Blue.*

A.

September 11, 8.45 P.M. 10 nearly mature larvæ of *P. rapæ* were placed in a cardboard tray (1·72 decimetre in length, 8·4 centimetres in width, and 2·7 centimetres in depth) lined internally with dark-blue paper, and with a clear glass front, which was directed towards a strong north-east light, the tray being placed vertically close to the window. A small amount of the food-plant (mignonette) on which the larvæ were found at Seaview was also included in the tray. No notes were taken as to the times of pupation.

Results.—Eight living pupæ were obtained, and of these 5 were crowded together in the angle made by two of the sides, one of which formed the roof in the position in which the tray was placed.

Of the 5 pupæ	3 were (3), 1 with more of the pigment patches than usual, although less of the grey dusting, and with a yellowish-pink ground-colour. The others lighter than usual for this degree, and with a pinkish ground-colour.
	2 „ (4), 1 typical, with a very pale pinkish ground-colour, and 1 with very little pigment and a pale yellowish-green ground-colour.
3 pupæ were isolated on the sides, and of these	2 were (3), typical, with a yellowish-pink ground-colour as far as it could be seen through the abundant grey dusting.
	1 was (4), with a distinct pinkish ground-colour, and rather more pigment than usual for this degree.

It is quite clear that the blue background was without special effect on the larvæ, acting merely as a moderately dark surface in abundant white light, with results intermediate between those of a black and of a white background.

Now that I have given the results of experiments in which all the colours of the spectrum have been used except violet, it will be well to make a tabular analysis of the whole, with the view of testing the relative effects of the colours, and of investigating the effect upon pigment of the predominance of rays of any particular wavelength in the light incident upon the larval surface, or of combinations which produce a corresponding effect on the Vertebrate eye.

Degrees of colour.	Analysis of results with *P. brassicæ*.						Analysis of results with *P. rapæ*.											
	(1) α	(1) β	(1) γ	(2)	(3)		Dark (1)	(1)	(2)	Dark (3)	(3)	Light (3)	Dark (4)	(4)	Light (4)	Pale (5)	Deep (5)	
II., B. White surface in very strong light	..	..	..	..	..	..	..	..	..	..	..	2	1	1	12	3	..	= 19
II., C., D. White surface in strong light	..	..	..	..	..	..	..	..	..	..	1	2	2	5	1	1	..	= 12
II., A. White surface in almost complete darkness	6	30	5	..	..	= 41	..	..	1	..	..	..	..	..	1	..	..	= 2
I., A. Black surface in darkness	3	5	..	..	..	= 8	..	..	..	..	2	1	..	..	1	..	..	= 4
I., B. „ „ somewhat shaded	..	..	..	..	..	..	..	4	1	..	3	2	..	..	..	..	..	= 10
I., C., D. „ „ less shaded	..	..	..	..	..	..	5	2	..	..	..	..	..	..	..	..	..	= 7
I., E. „ „ probably less shaded	..	..	..	..	..	..	5	6	..	..	..	..	..	..	..	..	..	= 11
III., A. Red surface in fairly strong light	5	5	1	..	..	= 11	..	..	..	..	..	..	..	..	..	..	..	
III., B. Red brick walls; illumination unknown, and probably variable	..	..	..	..	..	..	12	9	..	..	..	..	..	2	..	..	..	= 23
IV., A. Orange surface in fairly strong light	..	2	..	1	9	= 12	..	..	..	..	..	..	..	2	..	2	1	= 5
IV., B. „ „ „ „ „	..	1	1	..	..	= 2	..	..	..	..	..	..	1	..	..	..	..	= 1
V., A. Yellow surface „ „ „	..	..	1	1	1	= 3	..	..	..	..	..	1	..	..	..	1	..	= 2
VI., A. Green tissue-paper in a strong light	..	1	..	5	1	= 7	..	..	..	..	..	1	..	..	1	..	..	= 2
VI., B. „ „ „ „ „ „	..	3	..	5	1	= 9	..	..	..	..	..	2	..	2	2	1	1	= 8
VI., C. Pale bluish-green paper in a strong light	2	9	..	..	..	= 11	..	..	..	..	1	1	..	..	1	..	..	= 3
VI., D. Green tissue-paper and green leaves in a strong light	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	= 1
VI., E. Deep-green gate, somewhat shaded	..	1	..	..	..	= 1	..	1	..	..	1	1	..	3	..	..	..	= 6
VII., A. Darker blue surface in strong light	..	..	..	..	..	..	..	..	..	1	2	2	1	1	1	..	..	= 8
						105												124

These results are extremely interesting, especially as the effects of different-coloured light are so similar in the two species, both as to the formation of pigment and the production of green or other ground-colours. The effects in the former case are so uniform, and are so graduated in the successive colours which were used, that it is possible to give an approximate representation of the results by a graphic method making the abscissæ of the scale of wave-lengths, and each ordinate of a length which corresponds to the average amounts of pigment obtained from all the pupæ subjected to any one colour. Of course the results are only approximate, for there must be a good deal that is arbitrary in the selection of the scale of lengths to correspond to the different amounts of pigment in each degree of colour. The scales which were made use of in obtaining the averages were as follows :—

P. rapæ.		*P. brassicæ.*	
	millimetres.		millimetres.
(5) Deep green	5	(3)	14
(5) Pale ,,		(2)	28
Light (4)		(1), γ	42
(4)	10	(1), β	56
Dark (4)	15	(1), α	70
Light (3)	20		
(3)	25		
Dark (3)	30		
(2)	40		
(1)	50		
Dark (1)	70		

In order to decide upon the points on the scale from which to draw the ordinates, the colours employed in the above-described experiments were examined with the spectroscope, and hence a test of their purity was also obtained. The tints are indicated on Plate 26, figs. 16–21. The results were as follows :—

Dark-red opaque paper.—The reflected light was brightest from 60–65 on the scale below, the rest of the spectrum being very dim indeed, and even the chief reflected rays were not very bright. Hence the darkness of the tint.

Deep-orange opaque paper.—The reflected light was brightest from 57–65, the yellow being especially bright; the rest of the spectrum was very dim indeed. The chief reflected rays were much brighter than above, and the colour of the paper was far more brilliant.

Pale-yellow opaque paper.—The reflected light included a large part of the spectrum from 51–65, which was very bright, while the blue was reflected to a much less extent, and there was some more complete absorption between the blue and the green.

Bright-green tissue-paper.—The transmitted light (which was almost exactly the same as the reflected light, differing only in intensity) which had passed through one layer of this paper was especially dim in the blue, and in the red to a less extent, the

green passing through with hardly any diminution. The transmitted rays were especially bright from 51–59.

The pale bluish-green opaque paper made use of in Experiment VI., C. The reflected light differed from that transmitted through the green tissue-paper in the much larger amount of blue rays which entered into its composition. The red, orange, and yellow were also reflected to a slight extent, but were chiefly absorbed. The chief reflected rays extend from 45 to 57 on the scale given below.

The dark-blue opaque paper.—The chief reflected rays extended from 44 to 48, the rest of the spectrum being very dim. As the chief rays were not intense, the colour was a very dark blue.

It is, therefore, seen that the colours employed were fairly pure, although, of course, they were all mixed with an immense proportion of white light. The spectroscopic results indicate that each of the colours should be made into separate ordinates—the green tissue-paper and the pale bluish-green being separated because of the different amounts of blue in their composition. The red brick walls (III., B.) are omitted because of the reasons given at the end of the description of the pupæ found upon them, and because the spectroscopic character of their colour is unknown; and for the latter reason the greens in VI., D., and VI., E., are also omitted.

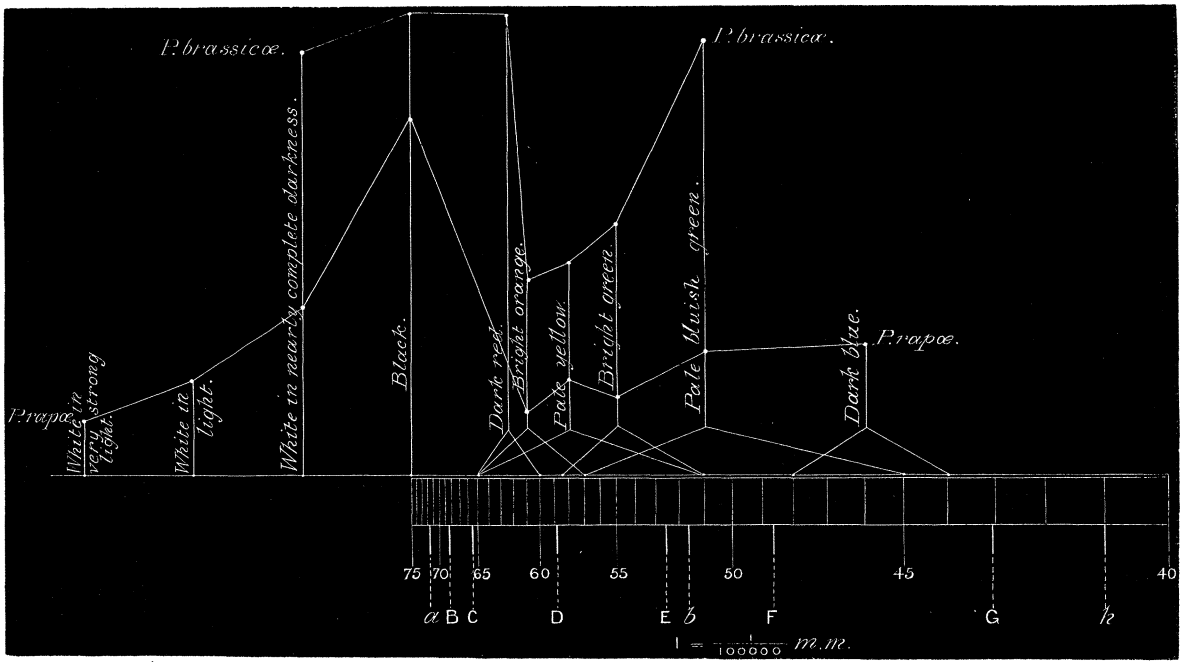
In the graphic representation (fig. 6) given below each ordinate which starts from the part of the base line which represents the visible spectrum is made to diverge and include on the scale the limits of the rays which were shown by the spectrum to constitute, at any rate, the chief part of the colour transmitted or reflected by the colour indicated on the ordinate. It should be noted that the *P. rapæ* line merely passes the ordinate for dark red, for there was no experiment to indicate the amount of pigment which is formed under the influence of this colour in the case of *P. rapæ*. To the left of the red end of the spectrum four ordinates are added to represent black and white under three conditions of illumination, in order to compare their results with those produced by certain parts of the visible spectrum.

The actual lengths were as follows:—

	P. rapæ.	*P. brassicæ*.
	millims.	millims.
White in very strong light . . .	7·36	
White in light	12·91	
White in nearly complete darkness	22·5	56·34
Black	47·81	61·25
Red	..	61·09
Orange	8·33	26·0
Yellow	12·5	28·0
Green	10·5	33·25
Pale bluish-green	16·66	58·54
Blue	18·75	

The results in the case of *P. brassicæ* are probably more trustworthy, because the numbers of pupæ employed in the various experiments were more uniformly large. The similarity of the results in the two species is very striking, and it would have been even greater but for the fact that the palest varieties of *P. brassicæ* retain more pigment than those of *P. rapæ*. Looking at the colours which retard the formation of pigment when they preponderate in the incident light, we see that they contain certain rays in common which are probably highly efficient in this respect, *i.e.*, the rays from 57 to 59 or 60. The immense difference between the action of red and orange corresponds to the fact that these active rays are present in the latter, and they are also present in the highly efficient yellow and bright green—that is, in all

Fig. 6.



the colours which retard the formation of pigment, except white, which, of course, contains these rays in addition to the others, although this is not necessarily the case, and it would be extremely interesting to experiment with whites from which this part of the spectrum is absent. Concerning such an experiment, it may be argued that this relation of colour to pigment formation is essentially protective, and is, therefore, concerned with the visual perception of insect-eating animals, and especially the Vertebrata; and if these latter cannot with the unassisted eye distinguish between a pure and an impure colour, or between a white which contains all the colours of the spectrum and one which contains only some of them, it would seem that the pupa would lose immensely if it were influenced by the one and not by the other, or in different directions by the two. It is, however, clear that we must only expect perfect parallelism between the sensitiveness of such widely separated animals as far as the stimulus is provided by colours which form the natural environment of the pupæ.

The observations upon the length of the preparatory period and of its constituent stages were insufficient, but they indicate a much greater length than in the case of *V. urticæ*. In most cases the period began when the larvæ were placed in the cylinders, &c., for no food was eaten by the majority of larvæ after they had been captured. This was because I always selected the largest larvæ from the cabbages and, as was previously explained, the shock of capture hastens the beginning of the period when the organisms are practically mature.

It is also noteworthy that there are some indications, as in the case of *V. urticæ*, that darkness may act in such a way as to prolong the whole period, and that possibly this increased length of time may bear upon the formation of pigment; or, conversely, that a shortened period may be brought about by certain reflected colours, and that the absence of pigment may ensue as a secondary result. This suggestion appears to be worth a careful trial, and, even if it does not contribute to the elucidation of this most difficult question, the protracted period in darkness may be useful to the organism in another way—to give it the opportunity of being affected by surrounding colours after change in the conditions of illumination. Thus, if the most sensitive part of the period were passed during the night, it would be to the advantage of the species for such a susceptible condition to be prolonged as far as possible. It may be that the absence or presence of direct light may be important in this respect, but the whole subject needs careful experimental investigation along the lines suggested by the results of the experiments described above.

Series 2.—Pupæ found upon Various Surfaces of Mixed or Indefinite Colours.

A certain number of wild pupæ were found upon walls, cement, &c., of colours which were not distinct enough to be included in the last series; and a large number of captured larvæ were allowed to pupate without any precautions to ensure uniformity in the colour of surrounding surfaces.

The results are described below:—

I. Mr. Harwood also sent me two pupæ of *P. rapæ*, found upon a cemented wall. They were both (3), with a distinct pinkish ground-colour, and one of them with unusual development of black patches on the dorsal surface generally, without any special development on the ridges and keel. These colours would be of protective value against the greyish surface.

II. September 20. Two pupæ of *P. rapæ* were found fixed to some yellowish-grey brick gate pillars, but shaded under the coping, at Yarbridge (Isle of Wight).

Of these . . . . . 1 was (3), pinkish, lighter than usual.
1 „ (4), pinkish, unusually grey, but with a smaller amount of pigment patches than usual.

The pupæ were well protected, for their colour harmonised with that of the bricks, &c.

III. October 12. A single pupa of *P. brassicæ* was found shaded under the coping of some new yellow brickwork at Seaview, Isle of Wight, in a somewhat shaded situation. It was a (1), β, typical grey dusting, pale-greenish ground-colour; normal black patches.

At the same time and place a number of pupæ of *P. rapæ* were found, nearly all of which were shaded by the coping of the brickwork. When the comparison took place eight pupæ were alive, and

Of these	1 was (2), typical; yellowish.
	4 were (3), typical; faintly pinkish.
	3 „ (4), all yellowish-pink; 1 with very small amount of pigment, the others with more than usual.

These pupæ also were well protected. The colour of the bricks was not sufficiently uniform or strong to be included under the yellow of the last series, and it was also complicated by the new whitish mortar and the new stone coping.

IV. September 15. A number of pupæ of *P. rapæ* were compared at this date, having been chiefly obtained from larvæ found upon mignonette in my garden at Oxford, while a few were produced from larvæ taken from the same food-plant at Seaview. The larvæ had been kept in two glass cylinders (about 8·4 centimetres in internal diameter and 1·8 decimetre in height), the tops being covered with white muslin, somewhat dull and grey from age, while the cylinders stood upon white plates and were almost filled with abundant food-plant. 31 pupæ were obtained, of which

7 were fixed to the two muslin tops, and of these	1 was (1), pinkish.
	4 were (4), 2 yellowish-green, 1 pinkish, 1 greenish.
	2 „ (5): both very pale yellowish-green, with a little pigment like that on (4) and in the usual positions.
19 pupæ were fixed to the glass of the two cylinders, and of these	2 were (1), 1 pinkish, 1 yellowish-green.
	6 „ (2) and (3), for these had not been separated at this time, the classification being extended later: 3 were pinkish, and 3 yellowish-green.
	9 were (4): 6 pinkish, 3 of them very faint and pale; 2 greenish, and 1 yellowish-green.
	2 „ (5), 1 very extreme and of a splendid emerald-green, with an almost complete absence of pigment in any form; the other pale yellowish-green, also with very little pigment.
5 pupæ were loose in the cylinders, and all	5 were (4), 1 pinkish and 4 greenish.

These results, upon the whole, show well the effects of white and green surroundings in strong illumination.

Series 3.—Transference Experiments.

A few transference experiments were made with the larvæ of these two species, and, although on a far smaller scale than with *V. urticæ*, the results prove quite conclusively (1) that the larva and not the pupa is sensitive to the colour of surrounding surfaces; (2) that there is some susceptibility to such influences during Stage III.

I. *Gilt, black, and white during Stage III.*—September 11. On this date seven larvæ of those described above in the two cylinders (see Series 2, IV.) were girdled on the glass sides, and small pieces of black, white, and gilt paper were glued under each to test the effect of these backgrounds during the remainder of Stage III. Two pieces of paper were placed under each in such a manner that the method of suspension was not interfered with, and yet a complete background was obtained. The experiment was conducted as follows :—

Sept. 11, 9.30 P.M. to 9.50 P.M.	Gilt paper fixed under 2 larvæ	White paper fixed under 3 larvæ	Black paper fixed under 2 larvæ	Larva girdled on stem of mignonette, pinned against gilt background.
Sept. 12, 8.30 A.M.	Both pupated . . Results: Both (4); 1 pinkish and 1 greenish; very little pigment	1 pupated . . . Results: A (4), pale pinkish; a good deal of pigment for this stage	1 pupated . . . Results: A (4), yellowish-green; very little pigment	Pupated. Results: A (2) or (3) then combined; yellowish-green.
„ 12, 9.50 A.M.	. .	. .	1 pupated; hence 12 hours of Stage III. spent on the black. Results: (4), yellowish-green with normal pigment.	
„ 12, 7.30 P.M.	. .	1 has pupated; perhaps about 18 hours of Stage III. on the white paper. Results: (4), pale pinkish; very little pigment.		
„ 12, 9.45 P.M.	. .	No further change.		
„ 13, 8.40 A.M.	. .	The last larva has pupated; at least 24 hours on the white paper, and probably 30 hours. Results: (4), pinkish; normal pigment.		

The pupæ were compared with those above, September 15.

In these pupæ there is no evidence that any effect was produced by the backgrounds during Stage III., or part of it. The results should be compared with those of Series 2, IV., which show the colours of the pupæ which had not been subjected to transference.

II. *Black and white during Stage III.*—September 16, a small group of larvæ of *P. brassicæ* were girdled upon a clear glass sheet which formed the covering of an ordinary wooden box. Other larvæ and freshly-formed pupæ fell down from the same sheet, and will be described below (III.). A sheet of white paper was fixed under half of the group and a black sheet under the other half, and a shelf was fixed between the two colours, covered with white paper towards the white side and black towards the black side, and the whole was placed vertically in a strong north-east light, close to the window. Thus the two groups of larvæ were exposed to black and white respectively during the remainder of Stage III., and there was reason to believe that the stage had not long begun. Notes were taken as follows :—

Sept. 16, 7 P.M.	Experiment began, the paper and shelf having been fixed.	
„ 17, 7.20 P.M.	1 larva on the white area has only just pupated	24 hours on white; thus Stage III. longer than this period of time. It is a (2), opaque greenish-white, rather yellow anteriorly; normal.
„ 18, 8.30 A.M.	Another larva on the white area has pupated a few hours	It is a (2), opaque greenish-white, lighter than the above, and smaller black spots.
	And 3 larvæ on the black area have pupated a few hours	2 alive, and both intermediate between (1), γ, and (2), because of the amount of grey dusting; very small black patches.
	And 1 larva on the black area was now pupating	Dead. Stage III. at least $37\frac{1}{2}$ hours.
„ 18, 11.40 A.M.	The last larva on the black has pupated	Dead. Stage III. longer than $37\frac{1}{2}$ hours.

It thus appears that the pupæ were slightly affected by the white and black surfaces, although to a very small extent. Stage III. may have been somewhat protracted in consequence of the glass being turned in such a position that the larvæ were head downwards, an attitude *never* assumed in this species before pupation.

III. *Black and white during Stage III.*—At 7.30 P.M., September 16, six moist and freshly-formed pupæ and seven girdled larvæ of *P. brassicæ* (alluded to above) fell down from a clear glass sheet to which they had been suspended (being the covering of an ordinary wooden box), owing to the continuous silken web which they had spun becoming detached from the glass. This was thought to be an opportunity of testing the sensitiveness of the pupa to coloured surroundings (as opposed to the larva), and therefore the pupæ and larvæ were each divided into two groups, and were placed on a black and a white surface. By 7.5 P.M., September 17, six of the larvæ had pupated, and the seventh pupated at 9.15 P.M. on the same evening.

Results.—Seven pupæ were living which had been exposed to the black surface:

Of these, 4 were (1), β, 3 yellowish-green, but very grey; 1 greenish.

3 „ (1), γ, ground-colour opaque whitish-yellow, almost like (2), but with larger black patches than in this degree, and even more developed than is usual in (1), γ.

Four pupæ were living which had been on the white surface :

Of these, all 4 were (1), β, 2 an opaque whitish-green, 1 yellowish, and 1 chiefly grey, but with a greenish tinge ; the grey very marked in all of them.

Here, again, the surfaces may have produced some slight effect, but the conclusions are not certain, because the pupæ already formed when the experiment began became intermixed with those which had been exposed to these colours during Stage III.

IV. On September 15 (see Series 1, I., C.) a girdled larva of *P. rapæ* (Stage III.) was found on a black tarred fence and was removed (4.15 P.M.), and was placed on white paper. At 5.30 P.M. on the next day it had pupated an hour or two, and the pupa when it took the permanent tint became a (1), very dark, and like those which had been found upon the fence on the 15th. In this case the powerful effects of the black surface during Stages I. and II. and the first part of III. could not be altered by the exposure to a white surface during the remainder (24 hrs.) of the last stage. This experiment is very conclusive against the former theory of pupal sensitiveness.

V. October 12, a single larva of *P. rapæ* in Stage I. was found crawling upon a chocolate-coloured paling at Seaview ; it was placed in a small chip-box with the other pupæ found on this date (see Series 2, III.) and became a (4), about normal, with a yellowish tinge. In this case the pupal colour appears to have been entirely due to the influence of the light-yellowish tint of the chip-box in which both the terminal stages were passed.

VI. October 5, six larvæ of *P. rapæ* were found on the green gate (described in Series 1, VI., E.), of which three were in Stages I. or II., and three in Stage III. (girdled). All six were placed in a cylinder (6 centimetres in internal diameter and 1·05 decimetre in height) covered with a single layer of black tissue-paper, and with a roof and floor of the same material. All the six pupæ which were obtained were alive when the comparison was made.

Of the 3 pupæ which had passed Stage III. in the cylinder and were girdled, 1 was (3), typical, yellowish.
2 were (4), 1 typical and yellowish-pink, and 1 was faintly greenish and very deficient in pigment.

The 3 pupæ which had passed part of stage in the cylinder were all . . . . (4), typical, 1 pinkish, 1 yellowish-pink, and 1 yellowish.

Here, again, some slight effect appears to have been produced by the transference, and the results harmonise well with those of all the other experiments of the kind.

In concluding the account of experiments upon these pupæ, it must be remarked that the effect of the coloured surroundings upon the dark pigment is, perhaps, the least important part of the changes produced, for there are other consequences which

seem to be much deeper in significance and far more difficult to understand. The black pigment patches and minute black dots are cuticular and superficial, while the ground-colours are sub-cuticular and deep-seated; and in the most brightly coloured pupæ they are mixed colours due to the existence of different pigmentary (and probably chlorophylloid) bodies present in the different elements and at different depths of the sub-cuticular tissues of the same pupa. In other pupæ no trace of such colours can be seen. Hence we see in these most complex and varied effects of the stimulus provided by the reflected light, which deepen into their permanent pupal condition very many hours after the stimulus has ceased to act, the strongest evidence for the existence of a chain of physiological processes almost unparalleled in intricacy and difficulty, while a theory of comparatively simple and direct photo-chemical changes induced by the stimulus itself without the intervention of such a physiological circle seems entirely inadequate as an explanation of the facts.

Observations upon the Colours of the Pupæ in the Genus Ephyra.

After the consideration of the variable pupæ of many species of Rhopalocera it is interesting to compare the results obtained after an examination of the equally exposed and variable pupæ of a single genus of the Heterocera—the genus *Ephyra*. In 1883 I had the opportunity of studying the life-histories of three species of this genus (*E. pendularia*, *E. omicronaria*, and *E. orbicularia*), and an account of the investigation is published in the 'Transactions of the Entomological Society of London,' Pt. I., 1884, pp. 50–56. A short summary of the results obtained is given below. The larvæ of *E. pendularia* are dimorphic in the last stage, appearing in the two most usual colours, green and brown; those of *E. omicronaria* are similarly dimorphic, but the brown forms are relatively rare; while the larvæ of *E. orbicularia* are variable. The dimorphism of the two former species extends into the pupal stage, the brown larvæ always becoming brown pupæ, and the green larvæ green pupæ. (The two forms of *E. omicronaria* are shown on Plate 26, figs. 22 and 23, natural size.) Hence the colour of the pupa can only be affected through the influences which determine the larval colour, and it has not yet been shown that the colours of these larvæ can be controlled, although, from many experiments on other larvæ, I think that the proof of such a relation to surrounding colours is likely to be afforded by experiment.

The pupal and larval dimorphism has no relation to sex or to any observable imaginal character. Statistics appeared to prove that the brown forms of *E. pendularia* (alone observed in sufficient numbers) are relatively abundant in the winter (larvæ and) pupæ, and green in the (larvæ and) pupæ of the summer broods. It was also shown that the relative preponderance of either form could be greatly increased by breeding from parents which possessed the same colour in the earlier stages. Observations upon the situations selected for pupation failed to establish any colour-relation; but the results were not convincing against the existence of such a relation,

for the experiment was not carried out in the best way: there was not a sufficient quantity of *both* colours in the surroundings.

Dr. WILHELM MÜLLER, of Greifswald, refers to the above account, and evidently regards the Ephyridæ as peculiar in this respect. His evidence is all the more valuable because of his careful work on larvæ and pupæ of Lepidoptera during many years spent in South America. He says ("Südamerikanische Nymphalidenraupen," SPENGEL, 'Zoologische Jahrbücher,' vol. 1, Jena, 1886, p. 234):—"Eine rühmliche Ausnahme machte E. B. POULTON, welcher feststellt, dass sich bei verschiedenen Species der Gattung *Ephyra* der Dimorphismus der Raupe bei der Puppe erhält, so dass helle Raupen nur helle Puppen, dunkle Raupen nur dunkle Puppen liefern." The colours of the pupæ being predetermined, and following rigidly the colours of the respective larvæ, it follows that these organisms afford an interesting contrast to all the other species of exposed pupæ described in this paper (for there is no colour-relation between the larvæ and pupæ in *Papilio machaon*, &c.), while special protective resemblances in the pupæ seem to be only possible as the results of the selection of appropriate colours upon which to pupate. In the above-recorded observations there was quite insufficient evidence to support the theory that the larvæ have any such power, but I do not think that they are by any means conclusive in the other direction.

SUMMARY.

The results of this paper may be shortly summarised as follows:—

1. The following exposed pupæ of the Rhopalocera have been proved in this paper to possess an adjustable colour-relation to their surroundings—*Vanessa Io*, *V. urticæ*, *V. atalanta*, *Pieris brassicæ*, and *P. rapæ*. The relation had been previously proved for some of these species, and for others, which I have not had an opportunity of investigating, *e.g.*, *Papilio nireus* and *P. demoleus*.

2. On the other hand, dimorphic pupæ which are closely allied to the sensitive forms may be uninfluenced by surrounding colours, *e.g.*, *Papilio machaon* and *P. polydamus*. In the genus *Ephyra* (Heterocera) the dimorphic pupæ are quite uninfluenced by their surroundings, the pupal colours corresponding to those of the dimorphic larvæ.

3. The previously accepted theory, which explained the pupal colour-relation as following from the action of light upon the moist skin of the freshly-formed organism, is entirely disproved, and it is shown that the influence works upon the larva during the period which intervenes between the cessation of feeding and pupation.

4. This intervening period was carefully investigated in *V. urticæ*, and it was found that, after ceasing to feed, the larvæ wander for a variable time, then rest for about 15 hours upon the surface selected for pupation, and finally hang suspended, head downwards, for about 18 hours, after which time pupation takes place. By transferring

the larvæ from one colour to another it was found that the colour influence works for about 20 hours preceding the last 12 hours of the whole period.

5. Blinding proved that the eyes do not form the organs which are influenced, and it was also shown that the complex bristles do not contain a terminal organ with this function. Experiments with conflicting colours appeared to prove that surrounding colours affect the whole surface of the larval skin, although parti-coloured pupæ were not obtained. (There is, however, some evidence for such a result in *Papilio nireus*.)

6. In all cases there are certain colours which produce no effects. In the Vanessidæ the brilliant metallic tints of the pupæ can be greatly influenced by the presence of gilded surfaces in the environment of the larva before pupation. This fact appears to prove that the metallic tints are essentially protective, and probably subserve concealment by their resemblance to glittering minerals, such as mica. This theory is confirmed by observations upon the habits of certain species with gilded pupæ. At the same time the gilded appearance has acquired another and opposite significance in other species, being of use in rendering the pupæ conspicuous, and thus acting as a signal of an unpleasant taste or smell.

7. The amount of pigment in the superficial layer of the cuticle in the pupæ of *Pieris brassicæ* and *P. rapæ* appears to be influenced by the spectroscopic composition of the light incident upon the larvæ before pupation.

Description of Plate 26.

Figs. 1-6, inclusive ; all × 2 diameters. These figures represent a series of the pupæ of *Vanessa urticæ*, ranging from the darkest to the lightest and most golden varieties. Fig. 1, the darkest, is that represented by the degree of colour called (1) in the paper. Fig. 2, rather less dark, is called (2) in the paper. Fig. 3 represents the degree called (3). Fig. 4 represents a normal (4) ; while figs. 5 and 6 represent respectively the degrees of colour called normal (5) and exceptionally gilded (5).

Fig. 7. Natural size. The yellowish-green and relatively gilded form of the pupa of *Vanessa Io*, obtained by the use of yellowish-green surroundings. Similar varieties occur on the leaves of nettle.

Figs. 8 and 9. × 7. These figures represent the left fore-wings and the exposed part of the hind-wings of two pupæ of *Vanessa urticæ*, showing the relative amounts of black cuticular pigment present (in the superficial layer of the cuticle) in two different varieties. Fig. 8 represents the degree of colour called (2), while fig. 9 represents that called light (3). The black parts of the networks alone represent black opaque pigment ; the less dark parts of the networks are not opaque, and let the light freely through

when they are examined as transparent objects; hence the amount of opaque pigment in the lighter figure (9) is very small indeed.

Figs. 10 and 11, both × 7, represent respectively the cuticle of the left pupal fore-wings of a green and a grey variety of *Vanessa Io*. There is seen to be an immense difference in the ground-colour as well as in the amount of black pigment. The dark networks seen in these and the two last figures are purely cuticular in position, and were all drawn from the empty pupa-cases from which the imagines had emerged. The dentated outline within the margin of all the fore-wings, and especially distinct in fig. 11, corresponds to the shape of the imaginal wing which was developed under this part of the pupal wing. In correspondence with this fact, the pupal pigments are altered over the area where the imaginal wing will develope. The pigmented lines indicating the nervures of the imaginal wing really stop short at the dentated margin, but they are prolonged beyond as irregular lines of pigment which produce the deceptive appearance of uninterrupted continuity. It was necessary to describe the appearance thus far, but it is a subject upon which I am now at work. The object of the figures is to give a representation of the relative amounts of cuticular pigment, and not to reproduce morphological features (viz., the venation, &c.) with exactness.

Figs. 12 and 13, both × 2, represent respectively a dark and a light gilded pupa of *Vanessa atalanta*. Although the golden appearance is so much less diffused than in *V. urticæ*, it is especially brilliant on the places where it does occur. These two varieties were respectively obtained by the use of dark and gilt surroundings.

Figs. 14 and 15, both natural size, represent respectively a green and a brown variety of the pupa of *Papilio machaon*. The green variety was obtained in *brown* surroundings, and the brown variety in *green* surroundings, and they are figured so as to indicate this relationship. Thus the species is obviously unaffected by the colour of its surroundings.

Figs. 16–21, inclusive, represent the colours made use of in experimenting with the larvæ of the Pieridæ. Fig. 16 = dark red; 17 = deep orange; 18 = pale yellow; 19 = green tissue-paper; 20 = pale bluish-green; 21 = dark blue.

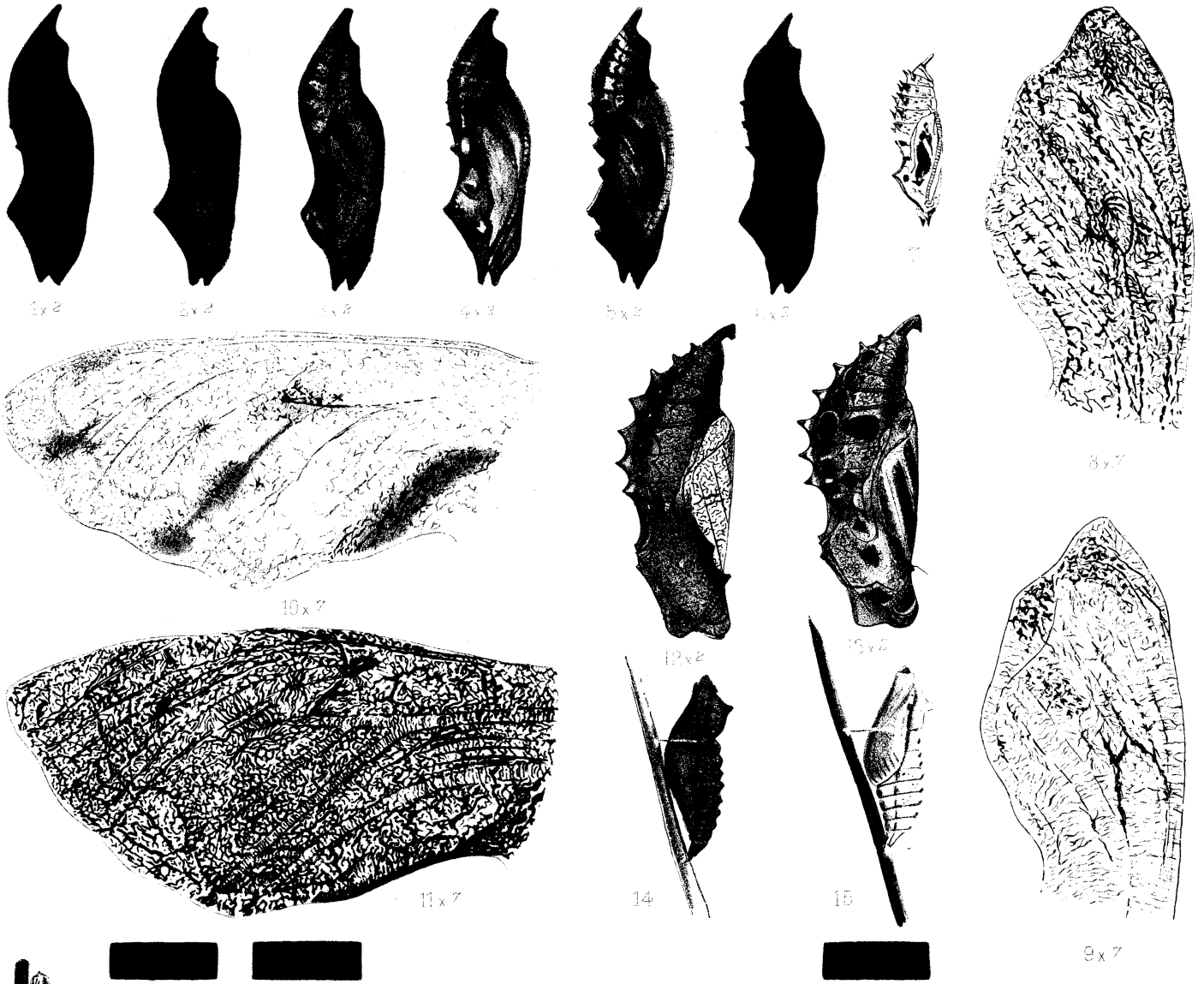
Figs. 22 and 23. Natural size. The brown and green forms of the dimorphic pupa of *Ephyra omicronaria*. The colour of these pupæ follows that of the respective larvæ, and is unaffected by surrounding colours.

Figs. 24–30, inclusive, all × 2, represent types of the different varieties of the pupæ of *Pieris brassicæ* obtained in the experiments. Fig. 24 represents the darkest variety, called (1), α, the ground-colour being of a greyish-orange; the less dark, fig. 25, represents a greyish-green, (1), β. Fig. 26

represents the less dark (1), γ, possessing a dark greyish-green ground-colour, but with an unusual absence of black patches. Fig. 27 represents a (1), β, with the normal black patches, but with the ground-colour unusually free from grey dusting, and therefore of a peculiarly bright whitish-green tint. This variety was produced in some instances by the use of a pale bluish-green background (fig. 20) and by means of a white background. Fig. 28 represents the bright yellowish-green variety called (2) in the paper, produced chiefly by the use of green tissue-paper surroundings. There is little black pigment present. Figs. 29 and 30 represent the bright-green variety called (3) in the paper, and chiefly produced by the use of orange surroundings. The latter figure is an unusually bright variety. The black pigment is even more deficient than in (2).

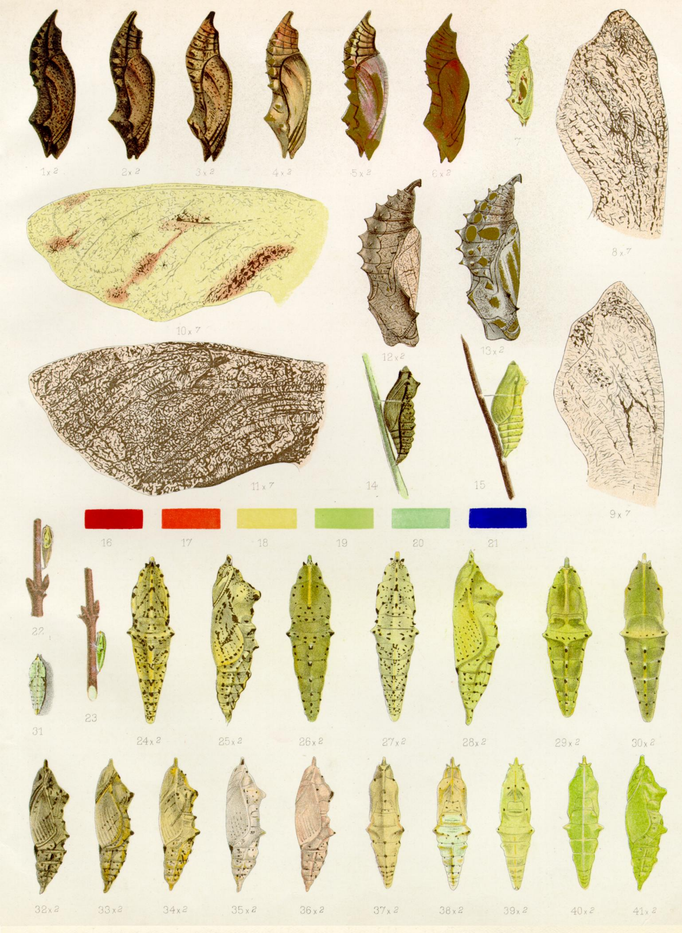
Fig. 31. Natural size; a green pupa of *P. rapæ*, called (5) in the paper, but with an unusual amount of pigment, so that, if it were less green, it would belong to the degree of colour called (3).

Figs. 32–41, inclusive, all × 2, represent the chief varieties of the pupæ of *P. rapæ*. Fig. 32 represents the darkest variety, called (1) in the paper. Fig. 33 represents a (2), being very dark, but lighter than the last. Fig. 34 represents a light (3), with the ground-colour distinctly visible through the smaller amount of pigment. Figs. 35–38, inclusive, represent various forms of the degree of colour called (4) in the paper, 35 possessing a greyish-white ground-colour, while 36 is distinctly pinkish, 37 yellowish, and 38 greenish, and forming the transition to the greener pupæ next figured. The amount of pigment is seen to be very small in pupæ of the degrees of colour called (4) and (5). Figs. 39–41, inclusive, represent the varieties included in the degree called (5), 39 being of a pale yellowish-green, and 40 and 41 representing two aspects of the brightest green variety.



E.B. Poulton. A. Robinson. } Pinx.ad

Lith. & Imp. Camb. Sci. Inst. Co.



Description of Plate 26.

Figs. 1-6, inclusive; all × 2 diameters. These figures represent a series of the pupæ of *Vanessa urticæ*, ranging from the darkest to the lightest and most golden varieties. Fig. 1, the darkest, is that represented by the degree of colour called (1) in the paper. Fig. 2, rather less dark, is called (2) in the paper. Fig. 3 represents the degree called (3). Fig. 4 represents a normal (4); while figs. 5 and 6 represent respectively the degrees of colour called normal (5) and exceptionally gilded (5).

Fig. 7. Natural size. The yellowish-green and relatively gilded form of the pupa of *Vanessa Io*, obtained by the use of yellowish-green surroundings. Similar varieties occur on the leaves of nettle.

Figs. 8 and 9. × 7. These figures represent the left fore-wings and the exposed part of the hind-wings of two pupæ of *Vanessa urticæ*, showing the relative amounts of black cuticular pigment present (in the superficial layer of the cuticle) in two different varieties. Fig. 8 represents the degree of colour called (2), while fig. 9 represents that called light (3). The black parts of the networks alone represent black opaque pigment; the less dark parts of the networks are not opaque, and let the light freely through when they are examined as transparent objects; hence the amount of opaque pigment in the lighter figure (9) is very small indeed.

Figs. 10 and 11, both × 7, represent respectively the cuticle of the left pupal fore-wings of a green and a grey variety of *Vanessa Io*. There is seen to be an immense difference in the ground-colour as well as in the amount of black pigment. The dark networks seen in these and the two last figures are purely cuticular in position, and were all drawn from the empty pupa-cases from which the imagines had emerged. The dentated outline within the margin of all the fore-wings, and especially distinct in fig. 11, corresponds to the shape of the imaginal wing which was developed under this part of the pupal wing. In correspondence with this fact, the pupal pigments are altered over the area where the imaginal wing will develope. The pigmented lines indicating the nervures of the imaginal wing really stop short at the dentated margin, but they are prolonged beyond as irregular lines of pigment which produce the deceptive appearance of uninterrupted continuity. It was necessary to describe the appearance thus far, but it is a subject upon which I am now at work. The object of the figures is to give a representation of the relative amounts of cuticular pigment, and not to reproduce morphological features (viz., the venation, &c.) with exactness.

Figs. 12 and 13, both × 2, represent respectively a dark and a light gilded pupa of *Vanessa atalanta*. Although the golden appearance is so much less diffused than in *V. urticæ*, it is especially brilliant on the places where it does occur. These two varieties were respectively obtained by the use of dark and gilt surroundings.

Figs. 14 and 15, both natural size, represent respectively a green and a brown variety of the pupa of *Papilio machaon*. The green variety was obtained in *brown* surroundings, and the brown variety in *green* surroundings, and they are figured so as to indicate this relationship. Thus the species is obviously unaffected by the colour of its surroundings.

Figs. 16–21, inclusive, represent the colours made use of in experimenting with the larvæ of the Pieridæ. Fig. 16 = dark red; 17 = deep orange; 18 = pale yellow; 19 = green tissue-paper; 20 = pale bluish-green; 21 = dark blue.

Figs. 22 and 23. Natural size. The brown and green forms of the dimorphic pupa of *Ephyra omicronaria*. The colour of these pupæ follows that of the respective larvæ, and is unaffected by surrounding colours.

Figs. 24–30, inclusive, all × 2, represent types of the different varieties of the pupæ of *Pieris brassicæ* obtained in the experiments. Fig. 24 represents the darkest variety, called (1), α, the ground-colour being of a greyish-orange; the less dark, fig. 25, represents a greyish-green, (1), β. Fig. 26 represents the less dark (1), γ, possessing a dark greyish-green ground-colour, but with an unusual absence of black patches. Fig. 27 represents a (1), β, with the normal black patches, but with the ground-colour unusually free from grey dusting, and therefore of a peculiarly bright whitish-green tint. This variety was produced in some instances by the use of a pale bluish-green background (fig. 20) and by means of a white background. Fig. 28 represents the bright yellowish-green variety called (2) in the paper, produced chiefly by the use of green tissue-paper surroundings. There is little black pigment present. Figs. 29 and 30 represent the bright-green variety called (3) in the paper, and chiefly produced by the use of orange surroundings. The latter figure is an unusually bright variety. The black pigment is even more deficient than in (2).

Fig. 31. Natural size; a green pupa of *P. rapæ*, called (5) in the paper, but with an unusual amount of pigment, so that, if it were less green, it would belong to the degree of colour called (3).

Figs. 32–41, inclusive, all × 2, represent the chief varieties of the pupæ of *P. rapæ*. Fig. 32 represents the darkest variety, called (1) in the paper. Fig. 33 represents a (2), being very dark, but lighter than the last. Fig. 34 represents a light (3), with the ground-colour distinctly visible through the smaller amount of pigment. Figs. 35–38, inclusive, represent various forms of the degree of colour called (4) in the paper, 35 possessing a greyish-white ground-colour, while 36 is distinctly pinkish, 37 yellowish, and 38 greenish, and forming the transition to the greener pupæ next figured. The amount of pigment is seen to be very small in pupæ of the degrees of colour called (4) and (5). Figs. 39–41, inclusive, represent the varieties included in the degree called (5), 39 being of a pale yellowish-green, and 40 and 41 representing two aspects of the brightest green variety.